Pope, Robin; Selten, Reinhard; Kube, Sebastian; von Hagen, Jürgen

Working Paper

Prominent Numbers, Indices and Ratios in Exchange Rate Determination and Financial Crashes: in Economists' Models, in the Field and in the Laboratory

Bonn Econ Discussion Papers, No. 18/2009

Provided in Cooperation with:
Bonn Graduate School of Economics (BGSE), University of Bonn

Bonn Econ Discussion Papers

Discussion Paper 18/2009

Prominent Numbers, Indices and Ratios in Exchange Rate Determination and Financial Crashes: in Economists' Models, in the Field and in the Laboratory

by

Robin Pope, Reinhard Selten, Sebastian Kube and Jürgen von Hagen

August 2009

Bonn Graduate School of Economics
Department of Economics
University of Bonn
Kaiserstrasse 1
D-53113 Bonn

Financial support by the
Deutsche Forschungsgemeinschaft (DFG)
through the
Bonn Graduate School of Economics (BGSE)
is gratefully acknowledged.

Deutsche Post World Net is a sponsor of the BGSE.

Prominent Numbers, Indices and Ratios in Exchange Rate Determination and Financial Crashes: in Economists' Models, in the Field and in the Laboratory *†

Robin Pope,[1] Reinhard Selten,[2]
Sebastian Kube,[3] Jürgen von Hagen[4]

1 Experimental Economics Laboratory, Bonn University; Address: Walter Flex Str 3, 53113 Bonn, Germany
Tels +49-228-731887, +49-228-4462880; Fax +49-228-4462881; Email Robin.Pope@uni-bonn.de

2 Experimental Economics Laboratory, Bonn University

3 Institute for Empirical Research in Economics, Bonn University; Max Planck Collective Goods Institute, Bonn

4 Institute for International Economics, Bonn University

Abstract

The prior paper in this sequel, Pope (2009) introduced the concept of a nominalist heuristic, defined as a focus on prominent numbers, indices or ratios. In this paper the concept is used to show three things in how scientists and practitioners analyse and evaluate to decide (conclude). First, in constructing theories such as purchasing power and interest parity to predict exchange rates and to advocate floating exchange rates, economists unwittingly employ nominalist heuristics. Second, nominalist heuristics have influenced actual exchange rates through the centuries, and this finding is replicated in the laboratory. Third, nominalist heuristics are incompatible with expected utility theory which excludes the evaluation stage, and are also incompatible with prospect theory which assumes that, while the evaluation stage can involve systematic mistakes, the overall decision situation is ultra simple. It is so simple that: a) economists and psychologists can mechanically model and identify what is a mistake, and b) decision makers can maximise. However, contrary to prospect theory, in the typical complex situation, neither a) nor b) holds. Assuming that a) and b) hold has resulted in the 1988 crisis from applying the Black Scholes formulae to forward exchange rates and contributed to sequel financial crises including that of 2007-2009. What is required is a fundamentally different class of models that allow for the progressive anticipated changes in knowledge ahead faced under risk and uncertainty, namely models under the umbrella of SKAT, the Stages of Knowledge Ahead Theory. The paper's findings support a single world currency rather than variable unpredictable exchange rates subjected to the vagaries of how prominent numbers, ratios and indices influence events via the models of scientists and practitioners.

Key words nominalism, money illusion, heuristic, unpredictability, experiment, SKAT the Stages of Knowledge Ahead Theory, prominent numbers, prominent indices, prominent ratios, transparent policy, nominal equality, historical benchmarks, complexity, decision costs, evaluation, maximisation, Black Scholes, Lehmann Brothers, sub-prime crisis, central bank swaps.

JEL Classification D800, D810, F310, F330

1 Introduction

This paper examines the role of prominent numbers in exchange rate determination. It uses the lens of SKAT, the Stages of Knowledge Ahead Theory, Pope (1983), Pope, Leitner and Leopold-Wildburger (2006, 2009), Pope, Selten, Kube and von Hagen (2008). SKAT delineates the four main stages through which a chooser progresses when seeking to reach decisions. Each stage pertains to a change in knowledge ahead.

In stage 1 the chooser negotiates to discover his available alternatives. Once alternatives are ascertained, the chooser has a change in knowledge ahead as he now knows his alternatives.

---

* The experimental design is that of Robin Pope and Reinhard Selten with valued input from Jürgen von Hagen of a distinct role for the government. The experiments were initially programmed and conducted by Sebastian Kube. The identification of the move of experimental participants toward the 1:1 prominent ratio and its statistical significance was made by Reinhard Selten. The general concept of nominalist heuristics and its use in economists' mechanical models of exchange rate determination was developed by Robin Pope who also wrote the original paper and all redrafts. Reinhard Selten and Sebastian Kube contributed extensively to the second draft and the articulation of nominalist heuristics. Reinhard Selten has also contributed to improving this third draft.

† We thank for comments on this and a related paper Daniel Read, Andreas Orland, an anonymous referee of this journal, and members of the *10th Experimental Economics Days* held in Dijon, May 2008; of the XIII International Conference on the Foundations and Applications of Utility, Risk and Decision Theory, Barcelona July, 2008; of the 12th Conference of the Research Network 'Macroeconomics and Macroeconomic Policies', 'Macroeconomic Policies on Shaky Foundations – Whither Mainstream Economics?', Berlin, October-November 2008; of the Conference of the Social Sciences Chapter of the German Languages Economic Association, April 2009; and of the Experiments in Financial Markets section of the Limits to Rationality in Economics and Financial Markets workshop held by the Strathclyde University's Institute for Advanced Studies, June 2009. We thank for information on Bayesian priors Arnold Zellner, for discussions on central bank currency swaps Barkley Rosser. We thank for research assistance Jingyi Jiang, and Deon Marais. We thank for funding the German National Science Foundation and the Center for European Integration Studies.

Revised version Tuesday 4th August, 2009 *Initial Version 23 October 2006*

He enters stage 2 of evaluating his alternatives. Once he has finished evaluation, he has his second major change in knowledge ahead as he now knows his choice. He has entered stage 3, waiting to learn the final outcome segment of his chosen alternative. Stage 3 ends with a further change in knowledge ahead. He has entered stage 4 wherein he knows the outcome of his choice, so that in this respect all risks and uncertainties are resolved – certainty reigns.

Stage 2, the evaluation of alternatives, is the focus of this paper. Stage 2 is ignored entirely in EUT, axiomatised expected utility theory, which assumes that the evaluations are so trivially easy to do perfectly that choosers can costlessly maximise in order to choose. The evaluation stage is considered in works on money illusion such as Shaffir, Diamond and Tversky (1997), and on editing and framing of probabilities as in Kahneman and Tversky (1979), and Brachinger (2006). But the situations analysed are so simple that users of these theories believe that they can identify the optimal decision and classify as mistakes deviations from it. As illustrated in the fairytale in Simon (1993), real world situations are too complex for any scientist or member of the public to do his stage 2 evaluation by identifying one alternative as optimal. When none can maximise, each uses short cut heuristics.[1]

To identify how scientists and economic agents do their stage 2 evaluations in real world complex situations involving exchange rates requires:

a) establishing a new theoretical entity, namely the concept of nominalist heuristics including prominent number ratios; and
b) abandoning standard purchasing power parity and interest parity models and indeed all maximising models within the umbrella of standard rank dependent theories such EUT, expected utility theory, or CPT, cumulative prospect theory – and modelling within an alternative umbrella theory, SKAT.

The prior paper in this sequel, Pope, Leitner and Leopold-Wildburger (2009) furnishes background on the *theoretical constructs* underlying a) and b). This paper furnishes evidence concerning nominalist heuristics in *one* application, namely prominent numbers and ratios in determining the exchange rate. The paper furnishes field evidence on the complexity problems encountered in evaluating alternative ways of predicting exchange rates (Part 2) and determining exchange rates (Part 3). It furnishes evidence of how scientists and practitioners alike resort to nominalism, ie a focus on prominent numbers, indices and ratios. Parts 4 and 5 of this paper furnish parallel laboratory evidence on the decisive role of a prominent ratio in exchange rate determination. Part 6 provides an executive summary, indicates ways of incorporating these nominalist effects into qualitative and quantitative investigations of the exchange rate process, and the paper's policy implications.

2 Field Evidence on Predicting the Exchange Rate

Consider a firm who in the future must pay for an imported item in a foreign currency and thus faces an exchange rate risk. It has discovered that it has three broad classes of alternatives as itemised in Table 1.

[1] When nobody can calculate a maximum, the notion of an approximation to the maximum is arguably ill-defined or empty. Thus there is no scope to discern if any heuristic approximates that unspecifiable maximum – expected utility theory cannot be justified as an approximation to optimal behaviour.

Table 1
Firm's Choice Set

	Broad Category	Number of Distinct Alternatives in this Category
1	*stay out of the foreign exchange market* and take what comes as the cost of the imports when the bill falls due.	One
2	*"hedge" against its own currency* in case this depreciates so that when the bill arrives it would otherwise have to pay more.	Numerous, as it can offer variable amounts of its own currency on the foreign exchange market up to its credit limit in borrowing from its domestic currency credit source, select different exchange rate agencies to convert the funds and different ways of investing them in the foreign country.
3	*"speculate" on its own currency appreciating* and thus deciding to borrow money abroad and bring home.	Numerous, as it can decide to offer variable amounts of the foreign currency on the foreign exchange market, up to the credit limit imposed by its foreign currency credit source, and select variable means of executing this and investing the speculative funds at home.

Note: For some firms, for some time periods, one of the methods of executing 2 and 3 is to buy either an off the shelf or else an over the counter (OTC) forward exchange rate derivative. OTC forward exchange derivatives became the norm for large firms who can afford the additional expense involved in having a tailor made product. OTC forward exchange derivatives are the only form forward exchange available for extended periods into the future. However such tailor-made derivatives are frequently so complex that neither party understands the exchange rate risks involved. See sections 2.3 and 2.6.4 below for examples resulting in bankruptcy for the buyer. On account of their dangers and contribution to the dot com bubble and to the 2007-2009 crisis, there have been calls for the abolition of all OTC derivatives, eg Tirole (2009).

The choice among 1), 2) and 3) rests importantly on how likely the firm's own country's currency is to stay steady, appreciate, or depreciate. In other words the evaluation of its alternatives depends importantly on the firm's exchange rate prediction. Predictions of the exchange rate influence the decisions of agents whose actions directly or indirectly influence the actual exchange rate.

This part of the paper documents the difficulties faced by that firm, and by any other chooser whose stage 2 evaluation, directly or indirectly, may influence the exchange rate – whether that chooser is an academic economist, or a central banker, or a member of the Treasury or of a private firm. The difficulties demonstrate the error in assuming that stage 2 can be trivialised or ignored altogether. Before documenting these difficulties it is necessary to dispel a misconception.

2.1 Misunderstanding the Forward Exchange Rate Market

Many believe that mispredictions of exchange rates are so costless that firms and governments should not bother to spend a moment predicting them, and as a consequence fail to notice that such mispredictions cause bankruptcies, along with personal and economic distress, social upheavals and governments turfed out of office. This is because many adhere to a myth, the myth that exchange rate insurance is virtually costless and ever available – by means of purchase of a derivative, forward exchange.

While quite a few point the Black Scholes formula applications as enhancing insurance products, the myth of safe cheap exchange rate insurance actually arose amongst academic economists prior to the widespread usage of that formula. The myth arose on discovering after the breakdown of the Bretton Woods Agreement, that exchange rates were dauntingly difficulty to predict, not an equilibrium breeze. Instead of facing the facts and repudiating wildly fluctuating exchange rates, most academic economists started pronouncing that

exchange rate changes hurt nobody since everybody can convert their exchange rate risk into certainty of no exchange rate risk at essentially zero cost. When this assertion is carefully examined, it can be seen on pure logic to be impossible to be true in any general sense.

It is hardly surprising therefore that empirical checks, eg McKinnon (2005), have disconfirmed the claim of universal cheap exchange rate insurance. Empirical investigations instead document the frequent non-availability and the typical high costs and dangers of hedging via forward exchange contracts. In 1998, false faith in safe, virtually costless exchange rate insurance precipitated imminent bankruptcy of a highly exposed hedge fund, Long Term Capital Management, that it required swift action on the part of the Chair of the US Federal Reserve System to avert a 1929 style depression. We discuss this case further in section 2.3, and in section 2.6 document other specific firms and governments who came to grief in trying to protect their firms and taxpayers with forward exchange rate derivatives and interest rate swaps.

This paper is part of the serious rigorous tradition in economics that repudiates the myth of safe virtually costless exchange rate insurance. It acknowledges the reality that in order for our firm to choose sensibly amongst its options in Table 1, predicting the exchange rate is an important part of its stage 2 evaluation. Before embarking on our field evidence on how academics, firms and practitioners go about predicting exchange rates, it is necessary to discuss the nature of this field evidence.

2.2 The Role of Individual People

Since stage 2, the evaluation of alternatives, is ignored entirely under expected utility theory and trivialised under prospect theory, academic economists and psychologists nurtured under these theories have an unduly narrow notion of field evidence on Stage 2. These two theories induce scientists to perceive field evidence as consisting exclusively of data to which regression tests are applied. This is because theories that ignore or trivialise the evaluation stage, entice scientists to assume that decisions are so similar to each other that decision makers resolve every problem in the identical way as if using quantitative formulae based on the following assumptions.

(i) Maximum expected utility can be instantly and effortlessly calculated so that Stage 2 evaluation can be skipped.
(ii) The influence of key individuals can be ignored.

But assumptions (i) and (ii) are a parody of decision making concerning exchange rates in the real world. The field evidence amassed in this paper is thus of an entirely different character. It involves looking at the details of what an individual academic or a man of affairs *actually* does when attempting to predict the exchange rate. Any academic would be outraged at the notion that his original unique modelling of exchange rates has unoriginal mass reaction characteristic (ii), as would any higher level practitioner.

Nobel prizes for instance are awarded to scientists for exhibiting the reverse of assumption (ii). Such scientists obtain Nobel prizes for being, according to their relevant academic peers, sufficiently original and influential as to change an aspect of academic thinking. Few academics declare that Nobel prizes are a mistaken concept because the individual scientist is irrelevant.

Some academics go even further and agree with Keynes who deemed that individual academics can alter policies in firms and official sectors, and routinely do so:

> The ideas of economists and political philosophers, both when they are right and when they are wrong, are more powerful than is commonly understood. [Keynes 1936, chapter 24, concluding notes]

Keynes himself is credited with having numerous policies implemented, including altering the course of exchange rate history through his role in organising the Bretton Woods exchange rate stabilisation system. But in *Inside the Economists Mind,* Samuelson (2007) cautions on page x (of his three page forward covering pages viii to x) that we academics overstate our influence and often merely utter what those supplying funds wish to hear. Samuelson is stating a middle position, not denying the scope for individuals to influence real world policies and thus prices such as exchange rates.

But in their research methodology, many economists and psychologists deviate from Samuelson's middle ground position. They take the extreme opposite position to Keynes, namely that named individuals have zero influence on the external world, ie that events in the external world arise exclusively from group reactions. There are exceptions, including that set of economic historians who examine the impact of key individuals on exchange rate – despite being criticised by other economic historians for going beyond mechanical modelling. By far the majority of economists and psychologists however conduct their research under the maintained hypothesis that exchange rates (and all other studied phenomena) arise *exclusively* from impersonal factors – and that none arise from the idiosyncracies of individual personalities, rivalries, friendships.

Of course few academic economists and psychologists believe that their own teaching and their own research is so utterly irrelevant to the real world as their research methodology implies. The reigning methodology thus reveals that most academic economists have failed to integrate the following two beliefs.

(a) My own individual decisions matter as reflected in *own* academic writings and *own* education of students who will either become academics or practitioners in the private or public sector and that is why I am paid and respected.

(b) When doing science in the form of constructing theory and collecting field evidence on matters such as exchange rate determination, I would be unscientific if I entertained the hypothesis that any individual's decisions matter.

The conflict between (a) and (b) hints that it is methodological bias to exclude the possibility of individuals mattering. This bias is ingrained, inculcated from undergraduate days and more forcefully indoctrinated in graduate courses.

To entice academic economists and psychologists to become more open minded and to abandon this ingrained bias, we appeal to two matters. One is the protest lodged in a full page advertisement in the American Economic Review signed by Paul Samuelson, other Nobel laureates and eminent economists with the below text.

> We the undersigned are concerned at the threat to economic science posed by intellectual monopoly. Economists today enforce a monopoly of method or core assumptions, often defended on no better ground than that it constitutes the 'mainstream'. Economists will advocate free competition, but will not practices it in the market place of ideas.

> Consequently, we call for a new spirit of pluralism in economics, involving critical conversation and tolerant communication between different approaches. Such pluralism should not undermine the standards of rigor; an economics that requires itself to face all the arguments will be a more, not a less, rigorous science.
>
> We believe that the new pluralism should be reflected in the character of scientific debate, in the range of contributions in its journals, and in the training and hiring of economists" [Hodgson, Maki and McCloskey (1992, pxxv)

Our second prong in enticing economists and psychologists to quit their presumption that individuals are irrelevant, is to appeal to another aspect of their methodology, their emphasis on testing theories by their predictions. In this respect we outline here some landmark exchange rate episodes. These episodes suggest how mechanical modelling crafted within the reigning methodology should not be regarded as approximately true. Rather it should be regarded as decisively disconfirmed since its predictions have failed catastrophically whereas in those episodes predictions made under the alternative methodology have been borne out.

We select here eminent protagonists who have straddled the academic – private investor divide in running huge investment funds while also published widely on their conflicting methodologies on whether or not single individuals alter exchange rates, Merton representing the mechanical methodology, and Soros representing the alternative methodology wherein key individuals can alter exchange rate history. This moreover is a set of landmark exchange rate episodes in which, after dramatic exchange rate events unambiguously disconfirmed the mechanical models methodology, in that: (i) Nobel laureate Merton switched in 2001 to endorse an "individuals can change exchange rate history" methodology; and (ii) there was a concomitant switch in membership of the Nobel prize committee and in what sort of research the Nobel prize committee announced that it sought to foster.

2.3 Soros and Merton

Soros, by at least the later 1980s, pointed to the key role of conflict and cooperation amongst official sectors in driving exchange rates after the breakdown of Bretton Woods. In his Institute of Advanced Studies Princeton University lecture series, he averred that mechanical general equilibrium finance models miss the role of key individual decision makers in the official and private sectors, and proposed in effect that official sectors cooperate on exchange rate issues, Soros (1987). But in academe mechanical modelling of exchange rates prevented his findings being perceived as scientific. This was transmitted also via university training to some in official sectors who pressed these officials to ignore exchange rate cooperation and concentrate on employing mechanical models to "fight inflation first", as documented in eg Pope (2008).

In the later 1980s, within official sectors the efforts at exchange rate cooperation that had been fairly successful in the Plaza and Louvre accords of 1985 and 1987, became increasingly difficult to maintain. Conflicts arose between on the one hand governments and Treasuries concerned about worsening unemployment, and central bankers on the other hand, some of whom were more concerned about inflation, and on the European front seemingly more concerned about where would be headquarters of the planned euro's central bank. On factors exacerbating conflicts, see eg Eichengreen, Wyplosz, Branson, Dornbusch and Fischer (1993) and Cobham (2002).

As 1992 advanced, Soros predicted in effect a failure of cooperation between the UK Treasury and the German central bank and a major sterling depreciation. Major international

financiers had noticed the accuracy of Soros' prior predictions of such failures. Speculators' imitation of Soros contributed to Black Wednesday 1992 when 1) sterling drastically depreciated at a massive loss to UK taxpayers and 2) the UK was forced out of the euro plans. In other words, Soros' predictions involving how named key UK official sector individuals would decide, were borne out. He (and others who imitated him) made massive profits against the Bank of England when it despaired of obtaining cooperation from Germany's central bank and depreciated the pound massively on September 16, 1992, forcing it out of the EURO process. The cost to Briitsh taxpayers of the depreciation (and conversely the gain to Soros and others), the UK Treasury put at 3.4 billion pounds.

Nevertheless to academics creating exchange rate models and associated field data, the named key individuals (in the UK Treasury and in the German central bank) who generated this collision course of extreme cost to the UK taxpayer and to world financial architecture, remained irrelevant. Black Wednesday had to be the consequence of mechanical factors – market fundamentals, coupled with overshooting and undershooting and groups of noise traders creating some gyrations around equilibrium, or other perturbations creating transient arbitrage opportunities. Indeed there was by the 1990s a veritable explosion of mechanically modelling and detecting arbitrage opportunities in exchange rates and elsewhere identifiable.

This explosion was spurred by developments of the Black Scholes formula for pricing derivatives, developments that netted Merton and Scholes the 1997 Nobel prize in economics. Their formula enabled investors to feel safe, to feel that they had a reliable mechanical means of pricing forward exchange rates and other derivatives and could ignore the role of individuals (like Soros and members of official sectors). Financial institutions were by now hiring hoards of Finance Department graduates educated to price derivatives employing the Black Scholes formula, and investments in Merton and Scholes' hedge fund, Long Term Capital Management exploded. Other investment funds combined imitating Soros' hedge fund with imitating Merton and Scholes' hedge fund.

By 1998 however, Long Term Capital Management, had so mispredicted the Russian rouble that it risked ushering in a 1929-style depression. Alan Greenspan, then Chair of the Federal Reserve Board of the US, is credited with averting this disaster, Davidson (2007, 2008). Greenspan at the time observed that the Black Scholes formula enticed financiers to feel safer than was warranted. Disturbingly numerous – perhaps even the majority of finance courses specialising in the mechanical methodology and Black Scholes formula applications– have proceeded in this millennium as if this decisive disconfirming event for the methodology did not occur. Likewise prime graduate levels texts, eg Duffie (2005) and Cochrane (2007) have not been adjusted to even mention how the Long Term Capital Management disaster disproved the purported application of these theories to the real world.

In contrast to this head-in-the sand approach of mainstream economists, in Sweden, the disaster was admitted to be a disaster. It was admitted that economics should be a scientific discipline where the real world can disconfirm a mechanical theory and put in disrepute the associated mechanical methodology. The committee that had awarded the Nobel prize for Black Scholes formula developments was replaced and the committee's mandate for selecting winners was altered to be more inclusive of sister disciplines like psychology and to be more pluralistic and less mechanical in methodology. In this latter respect, the new list of areas that

the Nobel committee proposes its award of Nobel prizes might in the future foster eclecticism in methodology gives the prominent position of being the final phrases to contributions that involve:

> less formalized confrontation of various hypotheses with empirical fact; or "simply" profound observation and nonformalized innovative thinking about economic issues [Lindbeck 1999, updated 2007]

In short, this mechanical model failed disastrously for individuals and risked a world-wide 10 year disaster. The failure led one committee, sensitive to its duty to contribute productively to society, to downplay its former focus on mainstream mechanical economic modelling and to draw attention to less formalised confrontations of hypotheses with empirical fact and to nonformalised innovative thinking.

In contrast to the failures of the mechanical modelling of Merton, Soros' less formalised approach allowing for the impact of individuals stood the solvency test through the East Asian and Russian currency crises. Indeed Soros is possibly one of the exceedingly few key investors to be making profits in the 2007-2009 crisis, Soros (2008, 2009). This enduring success over decades reinforces the other forms of evidence (that Soros details in his books) of there being no mechanical relation between the "fundamentals" of economic theorising and the prices of financial asset (like the exchange rate) – not even when the notion of equilibrium is extended to refer to decadal averages.

Soros' scientific understanding that key individuals matter is moreover supported by Merton (2001). In his presentation to the American Economic Association Merton offered his hindsight evaluation of his errors. He saw his errors as having used an exchange rate model that ignored the size of individual investment fund and the extent to which "successful" named investors are imitated.[2] The view that namable individuals alter exchange rate history is also endorsed in a retrospective on the 2007-2009 by another practitioner with experience in the areas of central banking, pension fund and hedge fund activities. Fisher (2009) observes, in effect, that field evidence constrained by equilibrium theorising mis-analyses and mistreats the complex financial system as if it were mechanistic in nature. Fisher furnishes the vignettes for his Stage 2 thinking of each trade that he proposed to his hedge fund. His vignettes do not fit the mechanical models any more than do Soros' illuminating vignettes of stage 2 evaluations. The introduction to section 2.5 of this paper documents academic economists' failure to predict exchange rates through their mechanical models that trivialize stage 2 evaluations and ignore the impact of key individuals.

Finally some economists and psychologists may wish to discard the above evidence of prediction failures of mechanical models and contend that the problem is simply that the correct mechanical model is yet to be devised. For such individuals no field evidence can alter faith. But for such individuals laboratory evidence can. This is because whereas in doing econometrics there is only one world history to examine, in the laboratory alternative

---

[2] Scholes (2009), while not denying the failure of the Black Scholes formula embedded in the mechanical efficient market hypothesis contends that no substitute exists. In this he is incorrect. SKAT elucidated in this paper affords the umbrella theory within which more realistic modeling of how actual decisions are made that set exchange rates etc, eg along the lines proposed by Soros. The substitutes however are unrecognizable as scientific models to those trained to believe models must be mechanical.

world histories can be examined by having separate sets of players decide in identical settings. Part 5 of this paper reveals that key individuals alter exchange rate history. Nothing is different except the personalities of those players.

2.4 The Role of Words in a Scientific as distinct from a Technical Contribution

As illustrated in section 2.3, as regards exchange rate prediction, there have been dramatic triumphs for theories that allow for key individuals over mechanical theories, and the role of key individuals is corroborated in laboratory experiments. The field evidence presented in this paper accordingly employs a methodology that allows for the individuality of each situation and the originality of each scientist and each practitioner in affecting the exchange rate. This does not reduce the paper's evidence to being soft, subjective, anecdotal, discursive, unfocussed vignettes as suggested by one reader.

It is an error to think that only mechanical theories enable the collection of hard, verifiable, objective data to enable the scientists to make generalizations that hold over extended time periods and across aggregates of different sorts of agents. As will be seen below, our field evidence enables *indisputable, objective, general conclusions to be drawn* over aggregates with respect to both individuals and over time spans. These generalizations concern complexity: the infeasibility of optimizing; and the resort to prominent numbers, ratios and indices in the battery of heuristics employed in stage 2 evaluations.

Likewise it is an error to think that scientific content rises with the ratio of equations and numbers to words. The contrary is generally the case in the discipline of economics. Economics concerns how people decide. To specify how people decide in their stage 2 evaluations and earlier stages in facing risk and uncertainty requires words. To specify this seriously involves much analysis concentrating on the connection between symbols, numbers and the real world events.

Explicating this analysis requires many words. Empirical presentations that fail to include enough words to be able to articulate what their numbers mean arise from negligence in doing serious science. They result in meaningless and misleading conclusions from misunderstood data.

Likewise theoretical presentations that fail to include enough words to explain the denotation of the symbols arise from negligence in doing serious science, from a failure to balance fondness of doing algebra with concern about what real world events the symbols might denote. This results in misleading and misunderstood conclusions on what the theory says about the real world.

When the misunderstood theoretical conclusions are misconstrued as economic science about the real world and connected to misunderstood data, they can yield disasters such as that portrayed in section 2.3. When economists continue to adhere to the belief that words are unscientific, their technical mechanical texts expounding the Black Scholes and other mechanical formula fail to be complemented with sentences describing what happened to the Long Term Capital Management Fund. Thereby economists fail to be rigorous and objective.

They fail to increase the scientific content of their output, and fail to contribute to the safety and improvement of the world. This paper seeks to help alter this shameful situation by using an adequate number of words to seriously relate its conceptual building blocks to real world events.

Section 2.5 contains our field evidence on how academic economists make exchange rate predictions, and their minimal success. This part of our field evidence takes the form of literature surveys on: a) academic economists' usage of short cut heuristics in the form of nominalism, a focus on prominent numbers, indices and ratios in their purchasing power and interest parity models of the exchange rate; and b) academic economists' extreme difficulty (virtually total failure in the short to medium term) in making reliable predictions.

Section 2.6 comprises our field evidence on how men of affairs predict the exchange rate and their frequent mispredictions. This component of our field evidence comprises: self-reports of central bankers and speculators on their inability to predict exchange rates; survey data on firms systematically mispredicting the exchange rate; and media reports of firms into receivership through their inability to predict exchange rates and governments facing investigation for their loss of taxpayer funds through faulty exchange rate predictions.

2.5 Academic Economists

When the fixed exchange rate system of Bretton Woods was abandoned, the anticipation of academic economists favouring floats was that they understood the equilibrating "fundamentals" and indeed could costlessly, accurately, instantaneously do their stage 2 evaluations to predict the exchange rate – and that there would be fewer and smaller exchange rate changes than under Bretton Woods, Friedman (1953). Such is necessary for good predictions. Such has not transpired, Kenen (2002). To the contrary, among themselves economists have invested now hundreds of thousands of hours attempting to predict the exchange rate.

Ironically this expenditure of vast numbers of man hours has not enticed academic economists to repudiate expected utility theory, which implies that real world agents can effortlessly construct models to predict the exchange rate, and instantly decide what to do. In short economists do not notice the peculiarity of assuming 1 when 2 and 3 are essentially indisputable facts.

1 Economists assume that real world agents are brilliant and effortlessly, instantly perform stage 2

2 Vast hoards of academic economists labour through whole careers trying to imitate these brilliant real world agents in the exchange rate markets

3 Few academic economists rate themselves as less brilliant than real world agents

When the peculiarity of a conjunction of 1, 2 and 3 remains unnoticed, this precludes the opportunity for rejecting expected utility theory on account of its omission of stage 2.

It is not merely a problem that academic economists have taken decades to try to perform their stage 2 exchange rate predictions while assuming that practitioners perform stage 2 costlessly in zero time. A second stupendous problem is the failure of these predictions. It is now nearly 40 years since the Bretton Woods breakdown, the time when academic economists in sizable numbers began to attempt to understand and predict the exchange rate. Yet the result is essentially a total failure. Economists now admit that their "fundamentals" equations have low forecasting power and perform badly out of sample, Engel, Mark and West (2007). Economists take comfort in the matter that for some models for some countries at a 4-year horizon, out of sample they (marginally) beat the random walk, Engel, Mark and West (2007). Indeed Pagan (oral discussion) argues that fundamentals only concern long term relationships, as when each exchange rate value and each causal factor (regressor) is an aggregation of events over a two to four year period.

This view emerging in the new millennium that “fundamentals” concern the ultra long run places academic economists’ exchange rate predictions outside the realm of being pertinent to firms, households or governments. This is because firms like households and governments can be bankrupted within this time span from major unpredicted exchange rate changes. In Keynes’ words, in the long run “we are all dead”. Numerous firms have been bankrupted and governments have been voted out from an unpredicted big exchange rate change – even if the predictions of these firm and governments would have been right if only people did not live in present but lived in some long run average mythical world.

Yet other economists uphold academic economists’ failure to predict the exchange rate as evidence that enough (non-academic) agents in the market have efficiently done their stage 2 evaluations, Engel, Mark and West (2007). Under the efficient markets rational expectations hypothesis, central bankers and firms who bewail losses of taxpayers and shareholders funds through the inefficiency of being unable to predict exchange rates are simply unappreciative of their marvellously efficient system, and of the stage 2 evaluations done for them by their economics departments and outside consultants. Thus the efficient markets hypothesis has black humour in its name.

Let us now look into some of the specifics of three prime ways that economists do their stage 2 evaluations in order to predict the exchange rate. For our purposes it is not necessary, and would generate a paper thousand of pages long, to examine every single “new generation” model produced each year in the hope of overcoming the failures of past models. It suffices for our purposes to document the matter with a few theories. We select three exceedingly generally used theories, namely the purchasing power parity theory, the interest parity theory or else to avoid predicting it under the efficient markets – rational expectations theory. Note that these three exchange rate theories need not be mutually exclusive theories for an individual economist. Some economists weld the three theories together. Below our purpose is to identify short-cut heuristics employed in each of these theories or components of an

overall theory, in order to allow economists to proffer exchange rate predictions to an agent such as our firm.

2.5.1 Purchasing Power Parity Heuristics

Realistically complex models, such as ones in which land (and its accompanying resources) is a fixed and relatively more important input into some goods, reveal that purchasing power parity would not set exchange rates, not even in long run equilibrium. Purchasing power parity theories however typically use the short-cut heuristic of ignoring the role of land and the country's non-renewable resource base. The standard purchasing power theories model exchange rates as a function of a single inter-country overall price ratio ie focus on *one* prominent ratio. This means that standard purchasing power theories ignore (amongst other things), the matter that in any country there are numerous prices and that between each pair of countries, key sets of prices move divergently. To name a few, there are consumer price indices, wholesale price indices, nominal wage indices, non-tradables price indices (that reflect housing booms and slumps), import price indices for services, import and export price indices for agricultural products, import price indices for mineral fuels, lubricants and related materials, and so forth. For instance in the case of Australia, exports comprise (1) mineral fuels, lubricants and related materials followed by (2) education. Over the June quarter 2008, in the September quarter 2008, prices for (1) rose 43%, while those for education remained almost constant. In the cost of exports, for the capital-intensive commodities, interest rates are arguably the prime cost, followed by wages, and vice-versa for education exports. In the six months to November 2008, interest rates as gauged by the central banks cash target, fell nearly 30%, while wages rose somewhat.

Such disparate price and cost movements lie outside most academic modelling of what drives exchange rates. Take for instance theoretical and econometric studies premised on purchasing power parity. In such studies, essentially arbitrarily, one price or cost index is prominent in the mind of the boundedly rational (ie human) economist and declared to be "the" price level in that country. Then a short-cut heuristic is employed, namely to ignore the fact that all the other prices and costs do not move in synchronism. Nor would they move in synchronism under standard theoretical assumptions – *unless there existed a symmetric pair of countries with respect to their real sectors and each using no land and other non-renewable resources*. A like prominent index is then taken for the paired country, and the two are conjoined in a prominent ratio that is the essence of the purchasing power parity theory. Purchasing power parity resting on the heuristic of a single prominent ratio is a lynchpin in numerous economists' exchange rate predictions and thus of their stage 2 evaluations.

2.5.2 Interest Parity – No Arbitrage – Heuristics

A second prime way that economists predict exchange rates and do their stage 2 evaluations is by means of interest parity models that connect forward and spot exchange rates to the inter-country interest difference. The discrepancy between the forward and spot rates is theorised

to be due to a disequilibrating "shock". When equilibrium is restored, there is: a) no discrepancy between the forward and the spot rate; b) the same spot rate in each period; c) no demand for a forward rate; d) no existence of the forward exchange rate market; and e) no discrepancy between interest rates in the two countries.

In just the same way as with the purchasing power theory, this theory rests on prominent indices and ratios. Depending on details concerning the particular borrowers and lenders, there is a plethora of interest rates in each country for any given duration. This plethora of interest rates does not move in synchronism, indeed at times some interest rates move in reverse directions from each other as in the 2007-8 US sub-prime mortgage crisis. In some countries, central bank discount rates dropped steeply while interbank lending rates rose steeply. Such wildly differing interest rate movements however are ignored in standard exchange rate models. Instead, in theoretical and empirical work, one particular interest rate in each country with a specific duration to match that of one forward rate is selected as a prominent index in the form of a short-cut heuristic. The disparate levels and movements of the other interest rates are ignored, as too those of forward rates of unlike periods into the future.

2.5.3 So-called Rational Expectations Efficient Markets Heuristics

Additional heuristics enter in theories whereby exchange rates are set "efficiently" in the sense of Fama (1965) or of Lucas' rational expectations (1976) wherein numerous EUT competitive profit maximizers use all available information in an efficient manner in setting exchange rates. There is the short-cut heuristic of ignoring problems of ever getting to an equilibrium especially as it may not be unique, and of its being unstable, problems explored in eg Grandmont (1985), De Arcangelis and Gandolfo (1997), Chichilnisky (1999), Hahn (1999), Drèze and Herings (forthcoming), Phelps (1999), Barnett and He (1999), Sordi and Vercelli (2003) and Dieci, Sordi and Vercelli (2006). There is the short-cut heuristic of assuming that if there are "irrational" or "noise" traders, they are insufficient in numbers to render the notion of an equilibrium exchange rate vacuous, but merely to cause some "over" and "under" shooting. There is the short-cut heuristic of treating the equilibrium exchange rate as a ratio that real world economic agents know when virtually no two academic economists agree on what the ratio is since each has his own distinct theory of how the economy works, Phelps (1999). There is the short-cut heuristic of treating the exchange rate as an equilibrium because the world is so simple that it perfectly repeats itself, Davidson (1984, 1988, 1991, 1993, 1996).

There is the short-cut heuristic of treating the equilibrium exchange rate as an externally given ratio independent of individual human action and market power despite the contrary evidence discussed in section 2.5 above. The heuristic of ignoring market power extends often beyond ignoring the power of major international financial firms. The heuristic is taken to the extreme of ignoring the market power of official sectors and employing efficient markets rational expectations models wherein all agents are powerless. In formal modelling, Hausken and Plümper (2002) is an important exception. The Hausken-Plümper model for

doing stage 2 predictions offers a game theoretic treatment of the incentives that central banks have to intervene to contain a financial crisis, and the role of the IMF in overcoming the collective action problem of joint intervention. This is an interesting insight into the array of central bank swaps and gentlemen's agreements that have emerged in September and October 2008 in response to the sub-prime crisis. See eg the 2008 US Federal Reserve Board announcements in this regard and note that via renewals, most of these swap agreements remain in force at the time of completing this paper draft, July 2009. The Hausken-Plümper model is also an interesting insight into the proposals of Bergsten (beginning in the 1970s) joined since 2008 by China and Russia and to a degree by India, for the IMF's special drawing rights to be modified partially or wholly towards a single world currency. See eg Bergsten (2009).

Economists' heuristic of ignoring the market power of official national and international organisations and of big private funds cannot be explained by economists not having caught up with the legal power of modern official sectors to print their own currency, and the size of some modern private funds. Market power in exchange rate markets is not a new phenomenon. The market power of official sectors and of major international financiers were crucial also to exchange rates in the prior century plus of the bimetallic and gold standard eras. The maintenance of those systems and currency unions within them rested on central bank cooperation, sometimes enforced by threats. This can be seen from the work of a set of economic historians who document how central bankers and major private international financiers such JP Morgan and Rothschild operated. These economic historians document how such agents performed their stage 2 evaluations of what was needed to maintain these systems and predict when there would be insufficient official sector cooperation and thus an exchange rate change. See Hooks (2005), Butkiewicz (2005, 2008) and Flandreau (2003a, 2003b, 2006).

2.5.4 Overview of Academic Economists' Exchange Rate Predictions Heuristics

In performing stage 2 evaluations, with few exceptions, economists have found it too difficult to incorporate into their models predicting exchange rates key issues like market power. Market power, as documented by the economic historians quoted in section 2.5.3, involves the complicated matters of cooperation and conflicts of public officials with each other and with key international financiers. Models incorporating all these evolving and dynamic personality and power structure issues would face tractability issues. Instead, for performing stage 2 and predicting exchange rates, academic economists employ algebraic models that fail empirically and that are rife with nominalism, a focus on prominent indices and ratios as short-cut heuristics for complex reality.

The economics profession has jointly invested over 35 years, and the entire academic careers of innumerable economists in this to date failed exchange rate prediction endeavour. This has not caused most academic economists, however, to conclude that performing stage 2 is difficult for themselves or for practitioners, and to realise that it is so difficult that they resort to nominalist heuristics. It is difficult for a scientist to discern that a stage is difficult if that scientist's theory excludes or trivialises that stage. The upshot is that most academic

economists continue to model exchange rate determination assuming that the non-academic sector have such an easy time doing their stage 2 evaluations that for practitioners their investment in stage 2 evaluations can be ignored (expected utility theory) or trivialised (prospect theory) and maximising procedures can be assumed.

2.6 Men of Affairs

Let us now consider whether predicting exchange rates and doing stage 2 of evaluating alternatives has proven easier for practitioners and whether in fact they use the maximising procedures assumed typically by academic economists. Here our field evidence of their massive difficulties has two strands, 1) accounts of private and public sector officials of how they evaluated and accounts of the mistakes that they made; and 2) public reports (ie other people's verdicts) of mistakes made by business economists, by public officials who lose taxpayers funds and by companies put into liquidation or receivership because of their mistakes in predicting exchange rates.

2.6.1 Bayesian Priors

One set of business economists use a stage 2 evaluation technique that warrants separate mention, Putnam and Quintana (1994). This technique employs new Bayesian statistical approaches for combining seven exchange rate predictions and investment strategies. A comparison is not made with the random walk, but with returns on investing in the S&P 500 for a particular period. It is contended that the exchange rate dependent investments exceeded returns on investing in the S&P 500 by a factor of 6 or 7 to 1, when employed out of sample. This is impressive, even if a technique that for one sample period resoundingly beat the S&P 500 is not information that a firm or official sector can readily use to assess confidence in the point estimate of the *single* exchange rate on which its decision rests in the first instance.

Necessarily the Bayesian priors technique stage 2 evaluation successes are reported ex post, and the paper does not provide us the readers with the scope to verify that they are precisely the ex ante predictions and a reader could himself compute from ex ante specified equations. The techniques are reported however as very similar to those of Zellner (1971). On the other hand, the era of prediction, the end of 1987 to the end of 1993, does encompass the exchange rate crisis of the UK (one of the currencies in their package). Still our firm could have more confidence in the technique if there were successor publications reporting that a like impressive result was obtained via the technique over sequential periods to date. Conversations with Arnold Zellner indicate that this might indeed be the case. Our firm can thus put Bayesian priors techniques in the possibilities category.

2.6.2 Chartists or Technical Analysts

To help firms do their stage 2 evaluations, a growing proportion of exchange rate dealer firms ignore fundamentals and sell predictions based instead on what has come to be termed chartism or technical analysis. Indeed the proportion using technical analysis is imputed to have reached 80%. Technical analysis can include standard prominent index heuristics such

as the Sharpe and Treynor ratios and Jensen's alphas. Technical analysis seeks to identify upper and lower barriers beyond which it is unlikely that an exchange rate will move, barriers at which it is predicted that there will be exchange rate turbulence, reversals of trends. The predictions can involve judgment in discerning the patterns, in which case it is sometimes termed chartism, or the predictions can be mechanical, the product of fixed statistical rules. A US survey found that by 1996-7, usage of prominent number barriers and other forms of technical analysis had risen to be the main exchange rate prediction tool of 30% of exchange rate operators, Cheung and Chinn (2001). A British survey found that for predictions of under a week, technical analysis predominates, Taylor and Allen (1992). By 2005, a former Bank of England and hedge fund (Global Macro) employee reported that the opinion in the City of London was that 80% of exchange operators employ prominent numbers from technical analysis to make money, Fisher (2009). He has further elucidated, that technical analysis also influences the trades of some fundamentalist traders since some of these know that charts can influence prices, and gives the following example.

> So if I'm an investment manager wanting to go long Japanese equities (for fundamental reasons), I will implement my position carefully, with charts in mind (e.g. if the market looks like it might go down for chartist reasons, I may hold off buying equities until it does). [Fisher private email to author 30 July 2009]

Short-range predictions based on some variants of chartism (technical analysis) have attractive statistical properties, eg Neely (1997), Osler (2000, 2003). But, as with the economists' models based on fundamentals, any technical analysis model faces the hurdle of being demonstrated to be robust out of sample.[3] Some technical analysis models on average marginally beat the random walk for out of sample horizons of a few hours to 15 days ahead, arguably as Fisher 2009) opines, through a self-fulfilling prophecy element when so many traders use related technical analysis models.

But for economic efficiency, the hurdle is higher than barely beating the random walk over a horizon of less than a week ahead. If they are to efficiently plan, and avoid massive losses, the public sector and firms engaged in real and financial imports and exports require models with far longer horizons and a far higher level of predictability.

2.6.3 Forward Premia

It might be thought that firms can predict the exchange rate from the forward market, as the efficient market rational expectations hypothesis would propose. This however is decidedly risky, above all when exchange rate changes are big. Just how disastrously risky is reliance on forward premia to predict the exchange rate, consider the years 1981 to 1984. In every single quarter over these four years, the expected depreciation of the US dollar against the average of the pound, the D-Mark, the Swiss franc and the yen for each of six major exchange rate expectation indices, exceeded 4% and for some exceeded 8%. Yet in reality in each of these years the US dollar appreciated, doubling in value for instance against the D-Mark

[3] Even as regards past data, there have been few efforts to compare the success of technical analysis and fundamental approaches in exchange rate predictions – there seems to be too few scientists with a mutual respect of both approaches to invest the effort in making such a statistical comparison.

between 1982 and 1985. For further details on this *five year era of systematic enduring erroneous* exchange rate expectations as measured by the forward rates, see eg Frankel and Froot (1987).

To see how disastrously risky it continues to be to rely on forward premia to predict the exchange rate, consider the sub-prime crisis of 2007-2009. It involved a totally unanticipated episode of a sharply increasing US dollar, contrary to all arbitrage-based exchange rate models. Eventually many realised its origin in the inability of agents to maintain or roll over their dollar obligations as desired, Soros (2008). This inability resulted in mass sell-offs of other currencies involved in carry trades to meet the US dollar denominated obligations. This inability was unpredicted since it involved liquidity constraints. Liquidity constraints are ignored in equilibrium exchange rate theories, including those that allow periods of over and under shooting of equilibrium. Attention to liquidity constraints is limited to non-mainstream analysts such as Davidson (2007, 2008) and Telser (2007a, 2007b).

The exchange rate disaster that otherwise would have ensued was mitigated by central bank swaps orchestrated to overcome the dollar shortage among major currency blocs, then extended to many other currencies. The September 2008 swap between the European Central Bank and the US Federal Reserve Board for instance coincided with an ending of the fall of the euro's value from being worth 1.7 US dollars in April, to being worth only little more than 1.25 US dollars by the beginning of September. With some wobbles, this swap facility to overcome the dollar shortage created by non-rolloverable debts, has allowed the euro by July 2009 to climb more than half way back to its April 2008 level, back up to being worth over 1.4 US dollars.

2.6.4 Firm Failures

Firms also have access to confidential exchange rate models to predict exchange rates and to do their stage 2 evaluations. These are not readily amenable to robustness checks by academics, so we judge them by our incomplete media information about the exchange rate profits and losses of those using these confidential sources. This information hints at firms lacking access to reliable exchange rate predictions, even when they are giant multinationals.

Firm losses on their foreign exchange accounts come often from efforts to hedge against exchange rate changes. Hedging for an extended period ahead is expensive, complex and not available to small firms. The terms are mostly confidential, so that it must be hard for the firm's agents to even discern what is the relevant future's price for one's particular firm looking at its range of future dates that matter, even if it accepted the efficient market hypothesis. Further, all government inquiries of which the authors are aware, report market power in exchange rate spot and forward deals. Small firms seek to avoid being caught in one of these bubbles, and larger ones seek to avoid causing one of them. This adds to the complexity of their evaluations of each hedging and speculation alternative.

The media reports firm errors in their hedging and speculation moves. Around the beginning of this millennium for instance, the giant multinational in zinc extraction, Pasminco, sought to

hedge its Australian operations. It sought to hedge against the anticipated appreciation of the Australian dollar against that of the US – zinc being sold in the international market at US prices. It purchased an exotic derivative for this purpose. It however failed to consider quite how unpredictable exchange rates are. Instead of appreciating at that time, the Australian dollar sank rapidly and drastically against the US dollar. The conditions of the purchased exotic were such that the company's liabilities rapidly exceeded its assets, forcing reconstruction. This is not an isolated case. Consider Long Term Capital Management's mis-prediction of the rouble-USD exchange rate.[4]

2.5.5 Official Sector Failures

The official sector of a country has other confidential means of predicting exchange rate changes not available to the private sector. But their methods do not yield them reliable predictions of the exchange rate either, as many of them admit. Their econometric models yield predictions deemed inferior to asking the wise their hunch, Pagan (2005). Central bankers bewail the inability of their research departments to furnish satisfactory exchange rate predictions, eg Jarle Bergo (2006), and Deputy Governor of the Norwegian central bank, Edward George (1998) then Governor of the Bank of England. This has been an enduring problem for the Bank of England of being startled by sterling's exchange rate changes and never, not even retrospectively, succeeding in understanding them. See for instance the illuminating summaries of its Monetary Policy Committee minutes and other public sources concerning the mystification of the Bank of England on why sterling so dramatically appreciated between 1996-8, then dipped, and why it had another dip in 2003, Cobham (2006). Paul Volcker, former Chair of the US Federal Reserve System, finds the unpredictability a ground for abandoning floats.[5]

Government treasuries (who via interest rate swap deals and so forth, acquire international currency / short term debt) suffer the same lack of access to reliable theories with reliable predictions on future exchange rates. Thus at about the same time that Pasminco went into reconstruction, the Australian treasury incurred losses on its international portfolio at the beginning of this millennium, losses borne by the general taxpayer. The losses were so massive that the country's central bank deterred a parliamentary proposal to have the interest rate swaps liquidated on the grounds that the sums involved would likely cause a further massive depreciation of the Australian dollar.

Official sector declarations in big countries have arguably unintentionally wrecked the economies in a number of smaller countries in 2008. In September Treasury Secretary Paulson allowed Lehmann Brothers to fail, unleashing a financial disaster. In response official sectors in the major European countries and in the US rescued on an ad hoc basis any major financial institution about to collapse and then in October made declarations that such

[4] Beware of the hindsight bias in which everyone sees that Pasminco was a fool in the exotic derivative it used in its attempt to hedge. In this context, one needs to bear in mind that Enron did not collapse solely through fraud. It collapsed partly also through the complexity and uncertainty of exotic derivatives being quite beyond the evaluation capacity of Enron employees (and most others).

[5] On a panel discussing exchange rates at the American Economic Association meetings in New Orleans, 2001, he constantly challenged his academic co-panelists, all enthusiastic floaters, to explain what was so good about floats when the associated exchange rate outcomes are unpredictable.

rescues would be continued in order to safeguard the financial system. But many other countries such as Iceland and Hungary were unable to offer such official sector rescue guarantees, and thus the set of declarations was followed quickly by exchange rate collapses, Soros (2008, pp162-163). The September and October central bank currency swaps that excluded some countries may have had a like unintended detrimental effect on the exchange rates of some not receiving the swap opportunity. In some cases later central bank currency swaps avoided further damage from these unintended detrimental exchange rate effects. For instance the European Central Bank's November 2008 swap agreement with Hungary's central bank seemed to have stopped the Hungarian Florint's fall, Darvas and Pisani-Ferry, 2008. Again, the European Central Bank's December 2008 swap agreement with Poland's central bank seemed to have stopped the Zloty's fall, Wagstyl (2008) cited in Hunter and Ryan (2009).

2.5.6 Overview of Practitioners' Exchange Rate Predictions Heuristics

In summary, it is non-trivial for practitioners to predict exchange rates including how their own actions alter exchange rates. But organisations like central banks and large multinationals have little in the way of cash constraints on buying predictions from the top international academics and other sources. Yet even these entities have public records of making grave errors for their own stake-holders and for innocent third parties. Practitioners use economists' models that, as demonstrated in section 2.5, are rife with nominalist heuristics, that is a focus on prominent numbers, ratios and indices. Additionally the private sector has come to rely increasingly on technical analysis which makes a very different use of prominent numbers, ratios and indices, and has, compared to academic economists' models, a whiff, but only a whiff, of out-of-sample prediction success in the ultra short run.

3 Field Evidence of Nominalism in Exchange Rate Determinations

Part 2 presented field evidence of nominalism, a focus on prominent numbers, ratios and indices, being rife in how scientists and practitioners predict exchange rates. This part presents field evidence of nominalism, a focus on prominent numbers, ratios and indices, determining exchange rates.

3.1 Exchange Rate Contracts

Nominalism enters exchange rate determination through the tendency to write international debt contracts in nominal exchange rate terms. Such nominalism fails to take into account the country locations of those engaging in the contract, the set of countries in which the lent funds will be spent, and the set of countries in which the borrower will subsequently spend the contingently repaid loan. It ignores the divergently moving pertinent price levels and third party exchange rates that should influence the exchange rate contract terms. Academic economists' modelling nearly always is only one step less nominalist – it tends to consider only the subsequent exchange rate adjusted as if the pair of countries each had only one price for all inputs and outputs, and as if third party country prices were irrelevant.

3.2 Inertia

Pope (1981, 1985a, 1987) found evidence that import competing firms made their decisions on the basis of *current* relative prices, including on the *current* exchange rate. They did not employ less nominalist procedures of looking at the bigger range of numbers required to make decisions on past trends or prior fluctuations in either the exchange rate or in other pertinent relative prices.

3.3 Mythical Benchmarking

Money is fiduciary, as too are exchange rates. What generates trust in a currency pertains to beliefs in a maintained order, in what are the fixed connections between numbers. As understanding of the world changes, previously conceived connections get condemned as mythical, as laughably nominalist.

Often opinion is mixed on what is mythical, what is real. Thus in this millennium international investors hire chartists, and partially base their decisions on their advice, and chartist theories employ prominent numbers and ratios and other connections between numbers. Many economists and others laugh at usage of such techniques, and deem that whiles prominent numbers and ratios may have some impact on exchange rates, the overall impact must be modest and transitory.

But when understandings are reasonably widespread, their impact on exchange rates can be decisive and endure over centuries or over thousands of years. We give but one example for countries bordering the eastern Mediterranean. Two widely used currencies in this part of antiquity were gold and silver for which an exchange rate of gold to silver remained at roughly 13:1 for centuries. This exchange rate of roughly 13:1 is dated by some as far back as the Croessus, but more reliably to the later Croesids with a Persian bimetallic fixed rate of 13.33:1, le Rider (2001). This prominent ratio of 13:1 has been the most enduring and decisive exchange rate determinant in the world, present already in ancient Persia, and continuing into the later middle ages in key trading centres of the Eastern Mediterranean such as Venice, eg Spufford (1986, Table II and, 1988, Table 7). Indeed on some interpretations of the evidence, when the band about 13:1 is 9:1 to 16:1, the exchange rate of silver for gold of 13:1 has been maintained over a very extensive geographic area for 5,000 years eg Myers (1976), Mayr (2004).

This exchange rate of gold to silver of roughly 13:1 pertained to what today we might see as the mythical association of gold with the sun and the silver with the moon plus a belief in harmonies between celestial and earthly relationships. The sun takes one year for a cycle through the ecliptic where the moon completes 13 such cycles in this time. This exchange rate was maintained via the incentives for the production of gold and silver. In the absence of wars and other major upheavals, this ratio could be maintained for extended periods given the fiduciary role of any currency. That is, given that many trusted in the ratio of 13:1 being the natural harmony – the equilibrium.

The prominent ratio of 13:1 did not entirely disappear from gold-silver exchange rates with the Renaissance bringing modern astronomy and new world discoveries vastly augmenting gold and silver supplies. An internet search demonstrates continued use of the gold silver ratio in the vicinity of 13:1 to advise clients. Eg Stanczyk (2009). What has altered is the reasoning for faith in this prominent 13:1 ratio. The reasoning has shifted from moon rotations about the sun to geologist's estimates of the earth's quantity of gold and silver, Sanders (2003). Of course geologists' estimates of minable gold and silver in the earth depend on faith that the prevailing price ratio of gold to silver will be pertinent when the ores are mined. That is, even today, a prominent ratio that has endured for thousands of years still has some role in the actual gold to silver exchange rate, even if a less decisive role than in antiquity of the middle east.

3.4 Historical Benchmarking

Prominent numbers have been interpreted as determining whether an exchange rate between a national currency and gold would be politically feasible, enforceable, stable, or with a likely trend path. Thus a stumbling bloc to the early resumption of the gold standard after World War 1 – given the costs of the war to Britain and her consequent indebtedness to the US – was the following. Britain had suspended conversions of the pound into gold during the war. She wished to return to the gold standard soon afterwards, but found that the historically prominent number ratio, the pre-war ratio of the pound to gold was too high a ratio at which to return. The other key countries' central bankers, however, considered that a resumed gold standard with the pound at any other exchange rate to gold could not be credible. They thus virtually forced the delay in when Britain "went back on gold" until 1925, and forced her going back at that historically prominent number ratio. In turn, since that historical benchmark was inappropriately high, Keynes campaigned for Britain to go off the gold standard. Britain's departure from the gold standard ensued within a few years. Thus one can interpret that particular historically prominent number as causing a delay in the effective resumption of the gold standard, of causing the British pound exchange rate of the mid 1920s, and causing Britain's depreciation of her currency a few years later. See eg Keynes (1989), Howson (1975), Earley (1976), Pope D and Pope R (1980), and Butkiewicz (2005, 2008). Again, after the demise of Bretton Woods, several countries retained a historical exchange rate from prior to the demise, or from some subsequent important date. Let us give two examples where the motivation of the unilaterally linking country, so far as we can glean from public information, has related to avoiding appreciations in order to promote exports. Austria maintained seven Austrian shillings to the DM essentially until the introduction of the euro. Until pressured early in this millennium to allow some renminbi appreciation, industrialising China had settled on maintaining a historical benchmark of the Yuan to the USD.

In other instances, historical benchmarking stems neither from the credibility issues as in the case of Britain's return to the gold standard in 1925, nor from helping trade flows. Rather it stems from a country's citizenry's national pride and concerns about terms of exchange

altering the distribution of wealth (and cost of imports). The most recent instance of this was East Germany. The exchange rate on unification with the west was set on a nominal equality basis, at 1:1 for prices, wages and savings below a particular level, depending on one's status. Nothing else was deemed politically feasible, even if some argued this high value for the East German currency relative to that of West Germany would hinder East Germany's economic catch-up. Savings above the designated limit moreover faced an exchange rate of 2:1 (two Marks to one DM), so here we have one more example of a prominent number ratio in the exchange rates employed in forming the re-united Germany.

3.5 Prominence in the Numbers Themselves

3.5.1 In Administered Exchange Rates

Prominent numbers often determine the exchange rate of a new currency introduced. Thus when the DM was introduced it was set at the round number of 4 DM to a USD. When it was decided that this was too high a value for the DM, the devaluation was another prominent number, a 5% devaluation. Likewise prominent numbers, not percentages with numerous decimal points, determined the size of other exchange rate changes during the Bretton Woods era. Prominent numbers continue to determine changes in pegs for those countries continuing on pegs or returning to pegs today. A prominent ratio was chosen for the introduction of the EURO to world financial markets on 1st January 1999.

3.5.2 In Speculation

Consider the technical analyst's prediction tools of a lower bound "support" through which a falling exchange rate is unlikely to lastingly pierce, instead on hitting this, likely to reverse, and of an upper bound "barrier" that an exchange rate is unlikely to lastingly surpass, instead on hitting it, likely to reverse. These lower and upper bounds tend to be prominent numbers. In speculative exchange rate dramas, "breaking the barrier" of round numbers makes headline news. Much interest was expressed for instance when the Euro initially slid below its introductory ratio 1:1 with the US dollar, and when it later rose above that nominal equality of 1:1 after 15th July 2002.

De Grauwe and Decupere (1992) concluded that attention to the prominent numbers of these "barriers" affected the actual USD yen ratio. Likewise a study of six technical analysis firms over 1996-8, Osler (2000, 2003) found that exchange rate dealers' attractions to the prominence of round numbers for these chartist "supports" / "barriers" may be the cause of the clustering observed in currency stop-loss and take-profit orders. See also Westerhoff and Reitz (2003) on the impact of "barriers" and "supports" on actual exchange rates

Such findings, however, like the media reports that abound in prominent numbers, pertain primarily to the ultra short run, durations of up to 15 days, with the focus on shorter durations of up to five days – not to any longer term enduring impact of the exchange rate over the period of concern to those involved in importing and exporting goods and services or longer term capital flows. There is a prevailing view that prominent numbers could not matter over these longer range horizons of a year plus, that over these longer horizons, the exchange rate would rest solely on fundamentals.

3.5.3 In Central Bank Rates

Official interest rates influence the exchange rate. In settings these, proportionate prominent numbers are the norm. This can be seen for instance in citations from FOMC archival notes of the US Federal Reserve, Goodfriend and King (2005). It can also be seen in the citations from the MPC minutes of the Bank of England, Cobham (2006). Market determined interest rates reported from these meetings are non-prominent numbers. But officially set interests rates are proportionate prominent numbers. The officially set rates rose or fell typically by 0.5% if a big change was selected, or by 0. 25% if a small change was selected.

3.6 Nominalism a Missing Link?

Does nominalism have overall systematic effects on floating exchange rates – in particular effects sufficiently enduring to matter for those involved in importing and exporting goods and services, and in capital movements concerned with returns over this intermediate time horizon? We might seek to infer this from the exchange rate prediction success of economists' public access theories of exchange rate determination. These theories ignore stage 2 of the decision process, and thus the role of nominalism. So if they predict well with robust statistical properties, it would seem that prominent numbers and nominalism only enter exchange rate determination episodically. As described in Part 3 above, we lack out of sample evidence that even the latest generation theories predict well. There is thus a possibility that the unreliability stems partly from omission, or inappropriate methods of inclusion, of the phenomenon of prominent numbers and nominalism effects.

However a leap to the conclusion that the unpredictability of exchange rates directly relates to their omission of nominalism is to ignore other issues that might explain the unpredictability. First these theories also omit stages 1 and 3 of the decision process. Second these theories are estimated as if exchange rate regimes and numerous other influences were stable for sizable periods, when in fact these influences were changing frequently. Third it could be that there is nothing systematic to be discerned in exchange rate movements, as argued under the efficient markets hypothesis.

4 Laboratory Experiment

A laboratory experiment allows for the evolving stages of knowledge ahead. Where there is sufficient time in a single experiment, it can allow for all stages, including stage 1 of discovering via research and negotiation, the choice set of each agent with a specific role, eg as the government, the central bank, a firm, a wage bargainer. Where experimental participants cannot be kept for this long, our case, the laboratory set-up fixes the choice set of participants in each role, ie the experimental set-up cannot investigate stage 1. But it can investigate the risk and uncertainty effects of the later stages 2, 3 and 4.

A laboratory experiment allows us to hold the exchange rate regime and other influences constant so that the estimates are not bedevilled by violations of the "other things constant" assumption in seeing whether the resultant exchange rate is white noise, as under the efficient market hypothesis. It thus lends insight on whether and how prominent numbers and prominent number ratios enter exchange rate determination in a more general and systematic

manner than the specific ways identified in Part 4 – and enter it over the medium term time horizon involved for international trade in goods and services and the associated medium term horizon capital flows.

Our design seeks to capture corporatist union-influenced continental Europe. Output prices are determined in a domestic Cournot market with five firms in each country, while imported materials prices are competitively determined, and wages set via centralized bargaining between an employer and an employee representative. We examine the effects of a dirty float in which central banks automatically intervene to support their exchange rate targets, and we vary the degree of transparency.

We make the context concrete to all participants, given the evidence that context affects decisions. The world is complex so that conclusions drawn from simplified set-ups may miss effects, and this matter is especially important when the study concerns complexities that generate the phenomenon of prominent numbers and nominalism. Our design is a compromise between the complexity of reality, and other constraints, including the number of seats in our laboratory, and the maximum time for which we keep participants in a session (one day). It is perhaps the most complex experiment performed in an economics laboratory other than those on the Sinto market, Becker and Selten (1970), Becker Feit, Hofer and Leopold-Wildburger (2006). More complex experiments have been conducted in psychology laboratories on economic decision-making, eg Dörner, Kreuzig, Reither and Stäudel (1983) and MacKinnon and Wearing (1983).

We restricted the complexity to what was teachable to advanced economics students for them to play it within a day, and analyzable with a game theoretic benchmark of an incomplete equilibrium. This incomplete equilibrium involves the non-co-operative Cournot solution for final output, and a Nash bargaining equilibrium in the nominal wage rate solution. This equilibrium in an incomplete mode was constructed for the design by Reinhard Selten. The incomplete equilibrium does not specify choices at all information sets and allows a player to neglect those branches of the game which, on being reached by his actions could not improve his payoff, no matter what is assumed about unspecified choices.

The set-up retains key features of economists' prominent ratio and numbers theories of exchange rate determination, including that in equilibrium purchasing power parity and interest rate parity both hold. It permits, but does not impose, game theoretically rational optimising behaviour. Under such behaviour, in its symmetric equilibrium that, as singled out by plausible selection criteria, is unique in real terms, purchasing power parity and interest rate parity both hold. There are two countries (the limit of our laboratory space of 18 seats, 9 for each country), each with its own currency, symmetric in every respect. In each country there is: 1 government, 1 central bank, 1 union representative, 1 employer representative, 5 firms who buy local and imported materials produced under competitive conditions that are used in fixed proportions to produce a homogenous final good sold in a Cournot market, with nominal demand set by the government. Firms buy their imports on credit, and must pay for them only next period. They face fixed costs, must produce at least a minimum amount, and face a capacity constraint on the maximum that they can produce. They can hedge or speculate in the current period, prior to its exchange rate being determined, and thus face uncertainty concerning both the current and the future exchange rate. Firm importing and

hedging / speculative activity helps determine the exchange rate whenever the two central banks conflict on their exchange rate goals.

4.1 Central Bank Intervention

If the two central banks have the identical aim for the exchange rate, and fully support their aim, they determine it. It is only in the case of conflicts between central banks –less than co-operation among central banks – that firms have an influence on the resultant exchange rate. This is the case even though there are third party exchange rates. To be a fully cooperating pair of central banks in maintaining their shared exchange rate aim means that the pair are willing, if need be, to sacrifice other goals such as their exchange rate desires as regards other currencies, or as regards the state of their own country's business cycle.

An example of inadequate central bank cooperation was when the UK suffered a speculative attack in 1992. The UK Treasury refused to raise its interest rate to stave off the attack when British firms were in a severe recession, but did not wish to depreciate and so be forced out of the process leading to being a member of the planned euro. It sought help to avoid such a depreciation through the German central bank intervening on the UK pound's behalf – but the reciprocal intervention did not come.

An example of adequate central bank cooperation was when France suffered a speculative attack in the following year, 1993. Again, the French central bank did not raise interest rates to keep parity with the DM, concerned at the depressed state of French industry. But in this following year Germany's central bank intervened on the French Franc's behalf. It intervened sufficiently for the depreciation of the French Franc to be modest enough for the rules to be doctored and France permitted to stay in the process leading to the euro.

A more recent example of central bank cooperation is in the set of central bank currency swap arrangements effected in September and October 2008 in light of the sub-prime crisis resulting in the collapse of Lehmann Brothers. Currency swaps have been organized between the US Federal Reserve Board, not only for numerous developed economies, but also between the US Federal Reserve Board with IMF input, to what that board deems developing countries with responsible monetary policies. See the Board's announcement of 29th October, which contains also a summary of its earlier reciprocal currency deals. In the same spirit, the European Central Bank has announced swap deals, eg with Denmark, and other central bank swaps have occurred, eg that of the Swiss national bank to aid the Polish central bank. Not all central bank cooperation and conflict is publicly announced. Some instances of cooperation and conflict over exchange rate aims are known only to the other official sector, though market participants attempt to guess and predict these events. Our experimental set-up included sessions where the exchange rate aims (and thus cooperation and conflict) are known only to the other official sector, and some where the exchange rate aims are public knowledge to all. On why the cooperation was publicly announced in September 2008, see the next section.

In our experimental set-up, in the case of central bank conflict, each central bank intervenes to support its exchange rate aim. It automatically intervenes up to a set multiple, ζ_1, of its export price in the prior period in the form of selling its own currency, if seeking to depreciate its currency against the wishes of the other central bank. It automatically intervenes up to a set multiple, ζ_2, of its import price in the prior period in the form of buying the foreign currency, if seeking to appreciate its currency against the wishes of the other central bank. Since countries have more limited scope to intervene in an effort to appreciate against the wishes of other central banks (this requiring foreign reserves), than in an effort to depreciate (this requiring them only to produce more of their own currency), $\zeta_1 > \zeta_2$. The actual exchange rate ensuing in these conflict situations is the ratio of currency offers made by the firms and central banks of each currency. However if this ratio is outside the range set by the two central bank exchange rate aims, the central banks cooperate further, sufficiently to keep the exchange rate at the nearest of their two exchange rate aims.

4.2 Official Sector Tasks and Instruments

We provide our official sector with only four instruments yet seven tasks. This reflects the reality that official sectors generally feel under-instrumented to achieve their objectives, and at times they and others call for new regulations to give them more instruments, or for the revival of lapsed instruments. Consider for instance the crisis of 2007-8 of housing asset bubbles in numerous countries. To curb them, the New Zealand central bank in its August 2007 submission to a New Zealand Parliamentary Committee into the country's monetary framework called for the introduction of an owner-occupied housing flat capital gains tax. To curb housing asset bubbles in New Zealand, Robin Pope (2007a, 2007b)) called for a capital gains tax on owner occupied houses, and for a like one on other assets, both taxes to be progressive with price rises, for a revival of quantitative lending directives and for more use of go-slow in rezonings. To curb asset bubbles in the US, Lester Telser (2007a, 2007b) appeals for a revival of two instruments that had fallen into disuse, the enforcement of the US Federal Reserve's commercial bank reserve ratio requirements and for capacity-to-repay constraints on mortgages issued.[6]

Our limiting the official sector to four instruments when tasked with seven objectives is likely in the right ballpark as regards the objectives to instruments ratio. In a more realistic and thus yet more complex environment, the number of objectives and of instruments would each be perhaps treble compared to what is in our set-up.

Thus our setting omits one instrument that most central banks possess, but (under pressure from the commercial banks) have used infrequently in recent decades as Telser notes, namely their scope to alter reserve ratios. Our set-up likewise omits two other instruments that all central banks possess and do use intermittently openly or behind closed doors. These are their scope to issue oral threats to banks who do not conform to the central banks wishes, and to issue public statements on likely future moves of central bank interest rates and future

[6] On variations over time in which of its many potential instruments a central bank uses, see eg Smits (1997).

readiness or otherwise of the central bank to provide liquidity to commercial banks. Our set-up also omits some instruments possessed by some central banks (and that used to be possessed by most central banks) such as supervision of commercial banks and quantitative lending directives. As regards objectives, our set-up lacks the multiple dimensions of central bank objectives concerning banking fragility and market need for liquidity – including variable definitions of assets acceptable to the central bank. It collapses all these dimensions into an invariant interest rate goal. Nevertheless our combined set of instruments and objectives suffices we believe to detect the key objectives and instruments of central banks operating in the post Bretton Woods environment.

Our set-up is decidedly more realistic in these respects than any theoretical model of which we are aware. In such algebraic models it is typical, if the official sector's objectives are modelled at all, to limit them to two – 1) some inflation aim, and 2) some output gap aim - and limit its instruments to one – typically an interest rate. Ie in these models, the ratio of targets to instruments is 2:1, a little worse than the 7:4 ratio of our set-up. Further, we are extremely unusual in delineating the separate instrument jurisdictions of government and central bank, a matter for which we are indebted to Jürgen von Hagen. In all these respects therefore, we find our set-up unbiased, indeed substantially more realistic than is the norm in either theoretical or empirical work.

In giving the central bank three instruments of setting an interest rate and announcing its price and exchange rate target, one reader expressed the conviction that central banks possess only one instrument. We infer the reader was convinced that setting an interest rate was the central bank's sole instrument. To enable readers to recognise that central banks routinely exercise the two other instruments of price and exchange rate targets included in our set-up, we give the following examples. We do so to enable readers to see that the three instruments we give our central banks in our set-up are instruments being used in this millennium.

On announcing price targets, central bankers in the US, the UK and the euro made announcements earlier in the millennium that inflation was a concern. By 2009 these same central bankers were announcing the opposite, that inflation was not a concern. These announcements are not idle chat. The central banks use them to tell the market, including exchange rate dealers, whether these central bankers are contemplating *future* interest hikes that could reduce inflation (in about three years time) and that could raise the exchange rate immediately. These central bank announcements on price targets and the inflation outlook affect commercial bank policy and exchange rates. The announcements indicate to commercial bankers whether or not to pass on changes in central bank interest rates to their own customers, and are often followed within minutes by a change in that country's exchange rate. In short these public announcements by central banks of price targets are powerful instruments for altering market behaviour.

Let us next explicate a central bank's public announcements of its exchange rate aims. Central bankers sometimes express their exchange rate aim in terms of cooperation with other central banks to keep exchange rates fairly steady. One of the landmark events in this regard is September 18, 2008. The world had had an imminent break down in the global financial

system with the US secretary of the Treasury Paulson permitting the collapse of the giant financial institution Lehmann Brothers with zero measures for an orderly winding up. The consequences would have been catastrophic but for the swift use of announced central cooperation. The US dollar had started rapidly appreciating in the prior quarter due to the subprime crisis. Those who had borrowed in US dollars could no longer rollover their debts as planned but had to buy dollars to repay their loans. This had caused already from July 2008 a worldwide shortage of US dollars and appreciation of the US dollar before the collapse of Lehmann Brothers, and with the collapse, the US dollar shortage was such that on many measures, there had been a collapse of the global financial system that would be difficult to keep secret for long. Retrieval from collapse is more likely to be fast with public announcements. One factor aiding retrieval from this collapse was that within a couple of days there was a public announcement of Ben Bernanke, the chair of the US Federal Reserve Board, that cooperative swaps had been organised for the next 6 months, swaps that were then renewed by both parties, and with trial and error, by July 2009 (the time of writing this paper), the USD to euro exchange rate is about back where it was before this potential exchange rate crisis erupted. The publicly announced swap procedure facilitated stabilising exchange rates by informing traders that central bankers were wary of big exchange rate changes and likely to counteract them.

Central bankers sometimes express their exchange rate in terms of wanting a strong or a weak currency for themselves, or about being concerned about their exporters (if the central bank wants a depreciation of its currency against the USD) or concerned about those who have to repay debts in USD (if the central bank wants an appreciation of its currency). Thus the UK government and Mervyn King the Governor of the Bank of England have at times in 2009 commented favourably on depreciations of the UK pound and unfavourably on any small appreciations of the UK pound as damaging exporters. Their public comments can be interpreted as informing the market of their intention to have a steady or depreciating pound and as engineering further falls in the UK pound simply by virtue of making their public announcements. Their public comments often save the central bank from needing to itself intervene in the exchange market in order to get a desired shift in the exchange rate. The financial press frequently reports an exchange rate moving within minutes in the direction desired by the central banker who used his exchange rate targets instrument to give a press conference.[7]

---

[7] Central bankers rarely express their exchange rate aim in terms of criticising and threatening another central for being uncooperative. They sometimes however indirectly publicly criticise that other central bank, eg by its not being included in a published list of central banks with whom there are swap announcements. The powerful instruments of publicly criticising and threatening other central banks is mostly left to the other branch of the official sector, the government. A government publicly threatens trade wars against uncooperative foreign central banks. Thus the US and the EUC so threatened Japan in the 1970s and continued doing so until about 1987, and then so threatened China in the 1990s and continued doing so until 2008. In each case the official sector instrument of publicly bad mouthing the other central bank had quite a bit of worldly success. Japan gave in and signed the Louvre Accord of 1987 that involved her in a massive and arguably ultra damaging devaluation against the US. China partially gave in a few years back and started appreciating against the US dollar at a gradual pace. That process of pressing China to depreciate essentially stopped in 2008 when the US decided it might be dangerous to let the US dollar collapse and started making opposite public announcements about valuing nice cooperative China.

It is hoped that this is sufficient information for all readers to appreciate that, along with their other instruments, notably changes in a key interest rate, official sectors have and routinely use as instruments announcements of price targets and of exchange rate aims. The objectives-instruments details of our set up are as in Table 2.

Table 2: Official Sector Objectives

Variables

q actual price of the home country consumption good
p_+ next period's target price of consumption good
p current period's target price of consumption good
e exchange rate, the number of unit of home currency needed to buy one unit of foreign currency, and thus as e rises, the home currency depreciates
m actual price of home materials in home currency
m^* actual price of foreign materials in foreign currency
r interest factor (1+ the marginal interest rate)
f exchange rate aim
B official sector (government and central bank) objective function
L actual employment

Parameters

r_0 ideal interest rate, set at 0.05
L_a minimal acceptable employment, set at 600
L_b maximum acceptable employment, set at 720
b_i weight parameters, i = 1..5. The b_i are positive constants, set respectively as 6, 6, 3, 3, 0.02 and 0.01

Official Sector Objective function

$$B = b_0 - b_1\left(\frac{p_+}{p} - 1\right)^2 - b_2\left(\frac{q}{p} - 1\right)^2 - b_3(r - r_0)^2 - b_4\left(\frac{m}{em^*} - 1\right)^2 - b_5\left(\frac{e}{f} - 1\right)^2$$
$$- b_6 \max\{L_a - L, 0\} - b_7 \max\{L - L_b, 0\}$$

The government sets nominal expenditure. The central bank sets its interest rate and announces its target price for the next period (not the current period), and its exchange rate aim. With these four instruments, as in real life, the official sector is under-instrumented to meet its seven goals: 1 keeping its target for consumer prices steady; 2, meeting that price target; 3, keeping its ideal interest rate; 4, maintaining its ideal level of competitiveness in its cost structure relative to the other country; 5, meeting its exchange rate target (a goal absent in the one currency case); 6 avoiding unduly low employment; and 7, avoiding unduly high employment. Although the decisions on instruments were allotted (as in most countries) either to the government or the central bank, the payoff was joint: both work for the national good. The specific penalties for the official sector deviating from each of its goals in our set-up are also in Table 2, including the real life issue of a higher penalty for too little employment than for too much.

4.3 The Private Sector

After the official sector has set and announced its four targets, in each country the union and employer representative bargain over nominal wages. These are the only players who can

communicate within a round. Their communications are in the form of computer entered text messages in the form of wage offers and demands that were public to all, not simply to the bargaining pair exchanging them. These are thus the only players for whom there are series of numbers, in the forms of offers and counter offers and associated words, *within* a round. The union representative's payoff is real wages measured as nominal wages deflated by the announced official sector target price, while that of the employer representative, the profit of the firms deflated by nominal expenditure. A strike ensues if after the set time allowed of 10 minutes, an agreement had not been reached. Then both negotiators receive zero pay. In the case of a strike: 1) there is an institutionally set minimum wage that is a fixed proportion of the target price, and 2) firms are subject to a lower maximum production level and a cut in nominal demand relative to that previously announced by the government.

Once the wage rate is announced for both countries, firms decide on output and on the amounts of a currency (home or foreign) to borrow to offer on the foreign exchange market in order to either hedge, speculate. The currency market then sets the period's exchange rate. Next the consumer market sets the consumer price, followed by firms paying for last period's imported materials, and each firm's account balances (from its home and foreign activities) flow to the firm's owners in their home country.

4.4 Rounds Interdependent, Sessions Independent Counterfactuals

A round is the above sequence of decisions and their outcomes played by both the official and private sectors. A round was played 20 times by the same participants, with a lunch break, typically after the 8th round. A session was a sequence of 20 rounds.

The rounds of a single session are interdependent, having in each successive round the same people and some common history. The first round was preceded by over an hour's instruction. The participants were economics students at Bonn University who had passed two or more years of economics, ranging in skill from those in their third year of undergraduate economics up to doctoral candidates.

There were six sessions run on 6 different days in 2003 with the exchange rate aims of the two central banks announced to all. An additional three sessions were run in 2005, with the exchange rate aims known only to the two central banks. Each of the 9 sessions contained different participants, and thus differing propensities to generate shocks, and all our shocks were caused by people – as have been nearly all our field shocks. We have 9 counterfactual worlds to aid us in assessing exchange rate regimes.

By the end of the associated set of experiments, we have almost exhausted our available pool of different willing participants. The sessions were typically on Saturdays, since few participants were available for an entire Monday to Friday weekday. No session had to be abandoned on account of participants becoming bored or too depressed at their earnings prospects to continue for the whole day. To the contrary, especially doctoral students, often

reported how interesting was the experience, and how instructive in macro-international finance. Many participants asked for permission to repeat but were refused.

Participants were paid according to their task achievement. Their earnings varied markedly depending on the session and role. They typically earned between the norm and double the hourly rate that students in Bonn obtain in outside casual employment. But there was disparity. Some earned virtually nothing, and others earned more than fourfold the normal student earnings rate.

5 Results

5.1 The Move of the Exchange Rate Toward 1:1

In the symmetric incomplete equilibrium, the exchange rate conforms to the purchasing power parity theory and the interest rates of the two countries offer no arbitrage opportunities as they are equal. The symmetric incomplete equilibrium is only unique in nominal terms. Unknown to participants, we start them in round one in such an equilibrium, but not with symmetry in nominal terms. At the start of actual round one, in nominal terms one country has its nominal wages and nominal expenditure 1.4 times that of the other country, and thus the exchange rate is such that this country pays 1.4 units of its own currency to obtain a unit of the other currency. In this equilibrium, interest parity holds and purchasing parity holds. If this equilibrium were to be maintained, the exchange rate would stay where it begins.

Starting in equilibrium, if nominalism does not operate, and standard game theory holds, we should anticipate no change in the exchange rate throughout the 20 periods. We should also expect no change under two heuristics that choosers might employ in stage 2 of evaluating their alternatives and the likely future exchange rate, namely inertia and historical benchmarking (since the opening exchange rate is the only striking historical event). A session with no changes in the exchange rate was not observed however. In every session the exchange rate changed.

The actual exchange rate is determined in this experimental set-up by decisions of the participants in the manner explained above in section 4.1, in effect the *ratio* of currency offers made by the firms and central banks of each country. Participants' choices of prominent numbers (by nominal equality or by historical benchmarking or by the mechanisms described in section 3.5 above) do not yield a prominent number for the exchange rate since this is the ratio of two sums of prominent numbers. But participants' choices swayed by such forms of nominalism can cause the exchange rate to move in a particular direction.

As measured by e, the number of unit of home currency needed to buy one unit of foreign currency, from the perspective of one country, in the starting equilibrium the exchange rate was 1.4. Thus e, from the perspective of the other country, its partner in trade and capital flows, was the inverse of this, namely 0.7143. The exchange rate has the lower bound of zero but no upper bound. In the Albers prominence theory (Albers 1998a, 1998b and 2001), there is a selection rule, but since it rests on their being a finite range of values from which to

select, it is here inapplicable. One cannot select the 3 to 5 most prominent numbers among the positive integers.

For a pair of countries viewing their exchange rates as respectively 1.4 and 0.7143, what then becomes prominent when the upper bound does not exist? One possibility is that inertia or historical benchmarking takes centre stage, with the exchange rate being regarded as equally likely to go up or down, so that player have a tendency not to alter the initial exchange rate. The other possibility is that nominal equality takes centre stage, with 1:1 becoming the prominent ratio for the exchange rate.

If the nominal equality of 1:1 did not exert any attraction, and instead the exchange rate changes involved random fluctuations, we should anticipate the final exchange rates to be equally likely to lie above or below the original exchange rates. This however was not the case. In each of the nine sessions, the exchange rate had moved in the direction of 1:1 by the last period, the 20th session. See Table 3, where all exchange rates are expressed from the perspective of country B, ie as beginning at 1.4.

Using the binomial exact test statistic, the probability of this uniform decline being by chance – and not due to nominalism – is 0.002, one-tailed, details in the Appendix. The results thus reveal the pronounced influence of the prominent nominal equality ratio of 1:1 on exchange rate determination. On superficial inspection it seems that players selected Albers-style prominent numbers for all prices and quantities. But there are altogether over 6,300 final number choices, and many times more in tentative number choices within rounds.

Table 3
Progression of the Exchange Rate of Country B Toward 1:1

Exchange Rate Aim	*Public Knowledge*						*Known only in the Official Sectors*		
Session	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Start in equilibrium	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
20 periods later	1.2	1.14	1.2	1.12	1.19	1.01	1.39	0.96	1

It will be an interesting future project to investigate whether the Albers Prominent Numbers Theory holds for firm choice of production quantities that have specific upper and lower bounds. It will be also an interesting future project to do two things. First, extend his theory with a nominal equality / fairness benchmark with potentially nominalist traits, to the majority of these other prices and quantities that lack specific upper and lower bounds. Second see for which roles the extended theory holds.

Despite the marked trend toward the nominal equality of 1:1, apparently aided by both firm and official sector anticipations in this direction, predicting the exchange rate eluded firms. They predicted its changes no better than a random walk, Kaiser and Kube (2009). This accords with reality, insofar as we can glean it from the incomplete records of firm failures in their exchange rate predictions reported in Part 3 above.

A further interesting research project, suggested by a comment of our helpful referee, would be to ascertain the extent to which countries that are asymmetric in their real sectors entice participants to focus on a different prominent ratio of the exchange rate. Would it, for instance, be the case that if one country were in real terms double the other, that participants would feel that exchange rates should move to render that country's currency worth double that of its partner?

These are interesting questions, but irrelevant to the key claim of this paper. The key claim of this paper is not that any one particular prominent ratio sets all exchange rates in all regions over all periods of time. Indeed our field evidence has demonstrated that many different prominent ratios have influenced exchange rates in different regions in different eras of time. The key claim of this paper is more abstract. It is that prominent ratios, numbers and indices influence actual exchange rates set. Indeed the field and laboratory evidence used corroborate this key claim demonstrates that in different situations different prominent ratios influence and sometimes entirely determine, the actual exchange rate.

5.2 Effect of Transparency in Central Bank Exchange Rate Aim

Consider now where along the spectrum from the initial exchange rate of 1.4:1 to the nominal equality of 1:1 countries had moved by the 20th round. The transparency or otherwise of central bank exchange rate aims seems to play a role.

5.2.1 The Non-Transparent Situation

In sessions 7, 8 and 9, the central bank exchange rate aims of the two countries are veiled from the private sector wage bargainers and firms. In this veiled condition, the outcomes are extreme. There is virtually no movement toward 1:1, session 7, or full movement to 1:1, session 9, or even "overshooting, session 8. In the additional complexity therefore participants may be interpreted as focusing their attention on either of two simple exchange rate prediction heuristics – inertia, or moving fully to the symmetric 1:1 exchange rate.

5.2.2 The Transparent Situation

In sessions 1 to 6, the exchange rate aims of the two central banks are public knowledge. In this transparent and less complex situation, there is less of a polarization. The move from the initial exchange rate of 1.4:1 in the direction of nominal equality with 1:1 is typically intermediate. Let us divide the distance between 1 and 1.4 into four quarters, and term the two middle segments "intermediate". Then in five of the six sessions the exchange rate on the 20th round lies in the intermediate segment. The outlier is session 6 which moved virtually the full distance to the prominent number 1:1.

5.2.3 Polarisation and Transparency

We may then hypothesise that non-transparent exchange rate aims generates more polarization. We can test this against the null hypothesis that the degree of transparency of the exchange rate aim has no impact on polarization as measured by the proportion of exchange rates in the intermediate segment of exchange rates between the initial exchange rate of 1.4 and the symmetrically prominent 1:1 exchange rate – ie as the proportion lying in

the range of 1.1 to 1.3. The null hypothesis is that the non-transparent condition derives from a population with no greater a propensity for distribution outside this intermediate segment than for the transparent condition. The probability of the null hypothesis being true is under 5%, on Fisher's exact one-tailed test, details in the Appendix. This hints that either nominalism or another rule of thumb, staying put, plays an even bigger role when the complexity, and thus uncertainty, in the situation rises.

6 Executive Summary and Modelling Implications

The evaluation of alternatives is stage 2 in the four stages through which decision makers progress after encountering a problem within SKAT, the Stages of Knowledge Ahead Theory, Pope (1983, 1995) and Pope, Leitner and Leopold (2006, 2009). It is a stage that EUT, axiomatised expected utility theory, excludes, and that prospect theory treats as so simple that scientists can discern whether other evaluators do it correctly or make a wrong choice. In exchange rate situations however there is too much complexity for anybody to maximise and discern optimal choices. In evaluating when nobody can optimise, in this paper we have concentrated on one nominalistic heuristic to which economic agents might resort, prominent number ratios. In Parts 2 to 5 we presented field and experimental evidence of their role in exchange rate determination. Below we summarise these findings and indicate how they may assist in future investigations of exchange rates – may assist a little in increasing understanding of exchange rate changes, and less certainly, assist a little in reducing the unpredictability of exchange rates.

6.1 Nominalism via Prominence in the Numbers Themselves

Administered changes in actual exchange rates are limited to prominent numbers, section 3.5.1 above. Speculators take an active interest in prominent numbers, section 3.5.2 above. Prices and quantities set by participants that enter the actual exchange rate process such as central bank administered interest rates are also limited to prominent numbers, section 3.5.3 above. Likewise in our laboratory set-up, the numbers chosen by participants for quantities and prices that enter the exchange determination were prominent numbers.

Econometric estimates in other areas have been enhanced from recognizing that variables assume values that are discontinuous over the real number line. Likewise theorizing and econometric estimation of exchange rates might benefit from imposing prominent number restrictions on administered exchange rates, and on some of the determinants of floating ones. It might also benefit from investigating prominent numbers as speculative attractors and repulsors, and from investigating Albers Prominence Theory for ascertaining what numbers are prominent.

6.2 Nominalism via Inertia

Pope (1981, 1985a, 1987) found in field data in the complex situation of a variable exchange rate, the nominalist benchmark of inertia in exchange rate expectations comes into play, as also for some other relative prices that enter exchange rate determinations, section 3.2 above.

Changes in production were based on the current exchange rate, not on extrapolating past exchange rate trends. In our experimental set-up, for the reasons given in section 5.1, it is infeasible to distinguish the inertia effect from either the game theoretic equilibrium exchange rate being an attractor, or the attractor being another form of nominalism, namely historical benchmarking. However one of these three effects – likely inertia –operated substantially, in that in one session by the final 20th round, the exchange rate had hardly moved, and that in most other sessions, it had moved only an intermediate distance to the attractor of the prominent nominal equality ratio of 1:1.

This suggests that there is room for a re-investigation of the common practice of assuming that expectations not pertaining to "fundamentals" are based on past trends. In complex environments without marked steady trends, an inertia attractor may be worth investigating for exchange rates along with the other attractors identified in this paper and summarized in sections 6.3 and 6.4 below.

6.3 Nominalism via Historical Benchmarking

Mythically and historically prominent exchange rate numbers have had decisive effects on actual exchange rates, effects that it was feasible to distinguish from inertia or a notion of the "fundamentals" being in equilibrium. In most of the instances cited in sections 3.3 and 3.4 above, the mythical or historical benchmark was not simply an influence, but virtually totally determined an exchange rate, often for a very extended period.

Including the idiosyncratic effects of myth and history in exchange rate modelling on any extensive scale would be demanding. Further including such myth and history effects goes against the ambition of many economists to model or estimate "economic" not "historical" or "metaphysical" causes. Such economists seek causes that are universal – that will hold "on average" in the future and did hold "on average" in the past independently of history and evolving metaphysical beliefs. Economics has had over a century of seeking to avoid immersion in details and being cataloguers of "accidents of mythology and history". We have to modify our imperial ambitions as economists of this brand however, and adopt a more eclectic methodological approach, if we are to incorporate the sort of field evidence identified in this paper.

When exchange rates were not totally decided by history – in the form of historical benchmarks – there is more scope for combining "on average" theorizing and econometrics with historical effects. Consider instances when an exchange rate enters a floating regime, or declares a cleaner float regime. At such moments, a historically prominent benchmark comes into existence, the prior one. In theoretical and empirical work embracing such moments, it could be useful to add gravity / attractor terms toward these historically prominent benchmarks and assess if this improves prediction, retrodiction / understanding.

6.4 Prominent Number Ratios

The attraction of some exchange rates to prominent number ratios is indicated by the field evidence, section 3.5.2. It is strongly supported by our laboratory experiment in which the

attraction to 1:1 was very highly significant, section 5.1. There is also evidence from our laboratory experiment that polarization in the form of an exchange rate either exhibiting inertia, or moving the full distance to another attractor, is accentuated when central bank exchange rate aims are non-transparent, section 5.2.

This happens despite our using a set-up that is far simpler than complex reality and that is begun in a symmetric incomplete equilibrium wherein both interest parity and purchasing power parity obtain. The situation is so artificially simple that there are only two currencies issued by two countries that are exactly symmetric in every real dimension. Nevertheless the participants are unable to understand the cause effect chains sufficiently, resort instead to the heuristic of the prominent 1:1 ratio.

The attraction of exchange rates to prominent number ratios is largely ignored in theoretical modelling of exchange rate determination over horizons longer than several days. The corresponding econometric estimates of quarterly and medium to longer term exchange rates typically impose no constraints on numbers chosen, and include no expectation terms pertaining to prominent number ratios. It could be useful to include gravity or attractor terms toward these. Likewise, when a new currency is formed, such as the euro, there may have been a period when the media focus on whether the exchange rate to the USD was above or below 1:1 had an impact, ie acted (perhaps still acts) as an attractor on the actual EUR-USD exchange rate. Again questions could be asked about the series of subsequent attractors for the euro noted by chartists as the Euro broke the 1.1.6 "barrier" in April 2009, and on its "bounce back" from plummeting to break downward the 1:1.3 "barrier", and its rise above the 1:1.4 "barrier" after the central bank currency swaps of September 2008 starting easing the liquidity crisis for US dollar debts that cannot be rolled over. Like questions can be asked for most other currencies, since most are perceived to have prominent number barriers by chartists.

6.5 Policy Implications

Nominalism, a focus on prominent numbers, ratios and indices, characterises essentially all agents involved in exchange rate determination and also academic economists' modelling the process. Further academic economists' models lack out of sample robustness within the short to medium time pertinent to firm, household and government policy making. These findings suggest that the retention of multiple currencies in the world can play no equilibrating role to enhance economic performance. Exchange rate stabilisation within a currency union allows other desirable goals to be met including freer capital flows, as noted by that father of the euro, Padoa-Schioppa (2004). Exchange rate stabilisation as via a single world currency, avoids the transactions costs emphasised by another father of the euro, Mundell (1961 and 2005). A single world currency avoids the dangerous beggar-thy-neighbour misapplications of Mundell optimal currency model as documented in Pope (2008). A single world currency is indicated to improve the macroeconomic management of an economy, in particular maintenance of international competitiveness. This is because official sectors are grappling with enough complexity without the extra instrument of being able to alter the exchange rate.

Having the extra instrument of manipulating the exchange rate cannot speed adjustment to "fundamentals" when after 35 years economists have yet to discern them, contributes rather to failure to maintain international competitiveness and other macroeconomic goals, Pope, Selten, Kube and von Hagen (2008).

In short this paper has found that variable exchange rates and multiple currencies leave countries subject to the vagaries of prominent numbers, ratios and indices. In conjunction with considerations that a single world currency eliminates associated transactions costs plus the multiple uncertainty costs for macroeconomic management and international borrowers and lenders, the findings of this paper favour the proposals of Bergsten dating from the 1970s and those of China and Russia dating from this millennium to investigate varying the IMF arrangements in the direction of a single world currency.

References

Albers, Wulf (2001), "Numerical Decision Processing Causing Stock Price Clustering", Homo Oeconomicus, 18 (2), 77-92.

Albers, Wulf, (1998a), "Foundations of a Theory of Prominence in the decimal System". Parts I-IV, Institute of Mathematical Economics, University of Bielefeld.

Albers, Wulf, (1998b), Prospect Theory and the Theory of Prominence as Solutions of the Same Stylised Facts., mimeo, Bielefeld

Barnett, William A. and Yijun He (1999) "Stability Analysis of Continuous-Time Macroeconomic Systems," Studies in Nonlinear Dynamics and Econometrics, January, 3(4), 169-188.

Becker, Otwin and R. Selten (1970), "Experiences with the Management Game SINTO – Market", in *Beiträge zur experimentellen Wirtschaftsforschung* (Contributions to Experimental Economics), **2**, Heinz Sauermann (ed.), Tübingen: J.C.B. Mohr (Paul Siebeck), 136-150,

Becker, Otwin, T. Feit, V. Hofer, U. Leopold-Wildburger, R. Pope and R. Selten (2006), "Männer schöpfen Märkte besser aus – Empirische Evidenz anhand des Unternehmensplanspiels SINTO-Markt" (Men Create Better Markets – Empirical Evidence of Enterprise Planning from Playing the SINTO Business Game", *Perspektiven der Wirtschaftspolitik* (Perspectives in Political economy), **7** (4), 445-458.

Bergo, Jarle, (2006), "Cyclical developments, monetary policy and the krone exchange rate", Speech by Deputy Governor Jarle Bergo, Østfold University College, Sarpsborg, 28 September.

Bergsten, Fred C. (2009) "We should listen to Beijing's Currency Idea", Financial Times April 08, 2009. http://www.iie.com/publications/opeds/oped.cfm?ResearchID=1180 accessed 13.07.2009

Brachinger, Hans Wolfgang, (2006), "Euro or 'Teuro'?: The Euro-induced Perceived Inflation in Germany", *DQE Working Papers* 5, Department of Quantitative Economics, University of Freiburg/Fribourg Switzerland.

Butkiewicz, JL, (2005), Eugene Meyer: From Laissez Faire to the Keynesian Revolution, presentation to the Southern Economic Association Meetings, Washington, November.

Butkiewicz, JL, (2008), Governor Eugene Meyer and the Great Contraction, Research in Economic History, 26, 273-307.

Cheung, Yin-Wong and Menzie David Chinn, 2001, Currency traders and exchange rate dynamics: a survey of the US market, Journal of International Money and Finance 20, 439-471.

Chichilnisky, Graciela, 1999, Existence and Optimality of a General Equilibrium with Endogenous Uncertainty', in G. Chichilnisky ed, Markets, Information and Uncertainty: Essays in Economic Theory in Honour of K.J. Arrow, Cambridge University Press, UK, 72-96.

Cobham, David, 2002, *The Making of Monetary Policy in the UK 1975-2000*, Wiley.

Cobham, David, June 2006, "The overvaluation of sterling since 1996: How the policy makers respond and why", *Economic Journal*, **116**, F185-F207.

Cochrane JH. Asset Pricing. Princeton University Press: Princeton; 2005.

Darvas and Pisani-Ferry, 2008, 'Avoiding a New European divide' bruegelpolicybrief 10 December, http://www.bruegel.org/uploads/tx_btbbreugel/pb_191208_Avoiding_a_Euro_dividde_ZD_JPF_01.pdf

Davidson, Paul (1984) "Reviving Keynes's revolution", Journal of Post Keynesian Economics, 4, 561-575.

Davidson, Paul (1988) "A technical definition of uncertainty and the long-run non-neutrality of money", Cambridge Journal of Economics, 12, 329-337.

Davidson, Paul (1991) "Is Probability Theory Relevant for Uncertainty? A Post Keynesian Perspective", Journal of Economic Perspectives, 5 (1), 129-143.

Davidson, Paul (1993), "The elephant and the butterfly – Or Hysteresis and Post Keynesian economics", Journal of Post Keynesian Economics, 15 (3), 309–322.

Davidson, Paul (1996) "Reality and economic theory", Journal of Post Keynesian Economics, 18 (4), 479-508.

Davidson, Paul, 2007, 2008 (paperback edition), *Interpreting Keynes for the 21st Century vol 4: The Collected Writings of Paul Davidson*, Palgrave, Great Britain.

De Arcangelis, G., G. Gandolfo (1997) Nonlinear phenomena in economics: The exchange rate. Nonlinear Analysis 30 (2), 1043-9.

De Grauwe, Paul & Decupere, Danny, 1992, *Journal of international and comparative economics*, 1, 1992, pp. 87-101.

Dieci, Roberto and Serena Sordi and Alessandro Vercelli (2006) "Financial fragility and global dynamics," Chaos, Solitons and Fractals 29, 595-610.

Dörner, D., Kreuzig, H. W., Reither, F., & Stäudel T. (Eds.). (1983). *Lohhausen. Vom Umgang mit Unbestimmtheit und Komplexität* [Lohhausen. On dealing with uncertainty and complexity]. Bern, Switzerland: Hans Huber.

Drèze, Jacques H. and P. Jean-Jacques Herings, forthcoming, Sequentially Complete Markets Remain Incomplete, Economic Letters.

Duffie D. Dynamic asset pricing theory. Princeton University Press: Princeton and Oxford; 2002.

Earley, James S, (1976), "Domestic Monetary Management in Britain 1919-1938 by Susan Howson", Journal of Economic History 36 (4), 968-969.

Eichengreen, B., C. Wyplosz, W. H. Branson, R. Dornbusch and S. Fischer (1993), "The Unstable EMS," *Brookings Papers on Economic Activity*, Vol. 1993, No. 1, 51-143.

Engel, Charles and Nelson C. Mark and Kenneth D. West (2007) "Exchange Rate Models Are Not as Bad as You Think," prepared for the NBER Macroeconomics Annual, 2007.

Fama, Eugene F., (1965), "The Behavior of Stock-Market Prices", Journal of Business, 38, (1), 34-105.

Fisher, Greg, 2009, *Observations from the Coal Face – A Practitioner's Perspective*, presentation to Experiments in Financial Markets section of the Limits to Rationality in Economics and Financial Markets workshop held by the Strathclyde University's Institute for Advanced Studies, June 2009.

Flandreau, Marc, 2003a, Introductory Overview, in Marc Flandreau, ed, The Money Doctors: The Experience of International Financial Advising 1850-2000. London and New York, Routledge.

Flandreau, Marc, 2006. "The logic of compromise: Monetary bargaining in Austria-Hungary, 1867 1913," European Review of Economic History, Cambridge University Press, 10(01), pages 3-33, April

Flandreau, Marc, ed, 2003b, *The Money Doctors: The Experience of International Financial Advising 1850-2000*, Routledge, London and New York.

Frankel, Jeffrey A. and Kenneth A. Froot (1987) "Using Survey Data to Test Standard Propositions Regarding Exchange Rate Expectations," American Economic Review, 77(1), 133-153.

Friedman, M, 1953, The Case for Flexible Exchange Rates. University of Chicago Press, Chicago.

George, Edward, 1998, The Roy Bridge Memorial Lecture, April 1, 1998, http://www.bankofengland.co.uk/publications/speeches/1998/speech18.htm, accessed May 28, 2008.
Goodfriend, Marvin and Robert G. King, (2005), "The Incredible Volcker Disinflation, *Journal of Monetary Economics*, 52 (5): 981-1015.
Grandmont, J.M. (1985) "On Endogenous Competitive Business Cycles," *Econometrica*, 53, 995-1045.
Hahn, Frank, 1999, A Remark on Incomplete Equilibrium, in in G. Chichilnisky ed, *Markets, Information and Uncertainty: Essays in Economic Theory in Honour of K.J. Arrow*, Cambridge University Press, UK, 67-71.
Hausken, Kjell, Thomas Plümper (2002), Containing contagious financial crises: The political economy of joint intervention into the Asian crisis, *Public Choice* 111, 209-36.
Hooks, Linda M, 2005, The international lender of last resort: Europe in the nineteenth century, *Washington and Lea University* Williams School of Commerce, Economics, and Politics *Working Paper*, presented at the 2005 Southern Economic Association Meetings.
Howson, Susan (1975), *Domestic Monetary Management in Britain 1919-1938*, Cambridge University Press, London and New York.
Hunter, Richard J. Jr. and Leo V. Ryan (2000) "Poland, the European Union, and the Euro: Poland's Long Journey to Full European Integration," *Global Economy Journal*, Vol. 9, Issue 2.
Kahneman, Daniel, Amos Tversky, 1979, 'Prospect Theory: An Analysis of Decision Under Risk', *Econometrica*, **47** (2) 263-291.
Kaiser, J and S. Kube, 2009, 'Behavioural Finance meets Experimental Macroeconomics: On the Determinants of Currency Trade Decisions', *Journal of Behavioral Finance*, 10(1), 44-54.
Katz, Aryeh (2009) "Trading the Gold-Silver Ratio," http://www.investopedia.com/articles/trading/09/gold-silver-ration.asp
Kenen, Peter (2002) "Currency Unions and Policy Domains" in D.M. Andrews, C.R. Henning, and L.W. Pauly, eds *Governing the World's Money* Cornell University Press, Ithaca, http://www.princeton.edu/~pbkenen/recent.html.
Keynes, J.M., 1923, *A Tract on Monetary Reform* reproduced in 1989.
Keynes, J.M., 1936, *The General Theory of Employment, Interest and Money* Macmillan Cambridge University Press, UK.
Keynes, John Maynard, 1989, in DE Moggridge, ES Johnson, *The Collected Writings of John Maynard Keynes*, St. Martin's Press, for the Royal Economic Society, New York
Le Rider, Georges 2001, *La naissance de la monnaie: Pratiques monétaires de l'Orient ancien* (The Birth of Money: Monetary Practices in the Ancient East). Paris: Presses Universitaires de France.
Lindbeck. 1997, 2007, 'Do the Prizes Reflect New Trends in Economic Analysis?' *The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel 1969-2007*, http://nobelprize.org/nobel_prizes/economics/articles/lindbeck/index.html
Lucas, Robert E. Jr., (1976), "Econometric Policy Evaluation: A critique." in K. Brunner and A. Meltzer, eds. *The Phillips Curve and Labor Markets,* Vol. 1, Carnegie-Rochester Series on Public Policy, *Journal of Monetary Economics,*
MacKinnon, Andrew J. and Alexander J. Wearing, 1983, 'Decision Making in Dynamic Environments', in B. Stigum and F. Wenstøp (eds), *Foundations of Utility and Risk Theory with Applications*, D. Reidel, Dordrecht, 399-422.
Mayr, Richard (2004) "Das Gold-Silber-Ratio," www.goldseiten.de/content/kolumnen/artikel.php?storyid=198
Mckinnon, Ronald, (2005), Exchange Rates Under The East Asian Dollar Standard: Living With Conflicted Virtue, MIT, Cambridge.
Merton, Robert C., 2001, Comments on the Reasons for Long Term Capital Management's Problems, presentation, American Economic Association Meetings, New Orleans.
Mundell, R. (1961): "The International Disequilibrium System", *Kyklos* 14, 153-172.
Mundell, Robert, 'China should keep currency peg', lecture organised by the Chinese University of Hong Kong, with speech published by the China Daily, accessed 03.06.2003, www,chinadaily.com.cn/English/doc/2005-06/03/content_448457
Myers, C.V. (1976) *The coming deflation*. Arlington House, New York.

Neely, J. Christopher, 1997, Technical Analysis in the Foreign Exchange Market: A Layman's Guide, September/October *Review*. Reprinted in *The Market Technician,* The Journal of the Society of Technical Analysts March 1998. No.31.
Osler, Carol, 2000, "Support for Resistance: Technical Analysis and Intraday Exchange Rates", FRBNY Economic Policy Review 6 (2), 53-68.
Osler, Carol, 2003, "Currency Orders and Exchange-Rate Dynamics: Explaining the Success of Technical Analysis", Journal of Finance 58, 1791-1819.
Padoa-Schioppa, Tommaso (2004) *The Euro and its Central Bank*, MIT Press, USA.
Pagan, Adrian, 2005, Report to the Court of Directors of the Bank of England on the modelling and forecasting systems within the bank.
Phelps, Edmund, 1999, "Expectations in Economics and the Rational Expectations Debate", in Alessandro Vercelli and Nicola Dimitri (1992) Macroeconomics: A Survey of Research Strategies. Oxford University Press.
Pope Robin (2007a), Submission to the New Zealand Parliament Select Committee on Finance and Expenditure, Inquiry into the future monetary policy framework.
Pope Robin (2007b), Transcript of Video Conference with New Zealand Parliament Select Committee on Finance and Expenditure, Inquiry into the future monetary policy framework.
Pope, Robin (1983), "The Pre-Outcome Period and the Utility of Gambling", in B. Stigum and F. Wenstøp (eds), *Foundations of Utility and Risk Theory with Applications*, D. Reidel, Dordrecht, pp. 137–177.
Pope, Robin (1995), "Towards a More Precise Decision Framework, A Separation of the Negative Utility of Chance from Diminishing Marginal Utility and the Preference". *Theory and Decision*, 39 (3), pp. 241–265.
Pope, Robin and David Pope (1980) *of Money, Credit and Banking*, November, 678-682.
Pope, Robin E., 1981, *Revaluation: Help or Hindrance to Australian Manufacturing?* C.A.E.R. Paper No. 14, University of New South Wales, December, 1-84.
Pope, Robin E., 1985a, "Revaluations: Help or Hindrance to Australian Manufacturers?", in W. F. Gossling, ed, *Western Pacific Trade*, Input-Output Publishing Company, Suffolk, 75-104.
Pope, Robin E., 1987, Revaluations: Help or Hindrance to Australian Manufacturing?". PhD Thesis, University of New South Wales, Sydney.
Pope, Robin, Johannes Leitner and Ulrike Leopold-Wildburger (2006), The Knowledge Ahead Approach to Risk: Theory and Experimental Evidence, Springer Lecture Notes.
Pope, Robin, Johannes Leitner and Ulrike Leopold-Wildburger, 2009a, "Expected Utility versus Changes in Knowledge Ahead," *European Journal of Operations Research,* 199 (3), 892-901.
Pope, Robin, Reinhard Selten, Sebastian Kube (2009b), 'Nominalist Heuristics and Economic Theory', Working Paper, Department of Economics, Bonn University.
Pope, Robin, Reinhard Selten, Sebastian Kube and Jürgen von Hagen (2008), "Experimental Evidence on the Benefits of Eliminating Exchange Rate Uncertainties and Why Expected Utility Theory causes Economists to Miss Them", *Indian Journal of Economics and Business* 7(1), 1-31.
Putman, B., Quintana, J., (1993): "Bayesian global portfolio management", *American Statistical Association*, Bayesian Statistical Science Sect., Proceedings volume, 110-117.
Sanders, Franklin (2003) "The Gold/Silver Ratio Strategy & The Case for Silver," www.Gold-=eagle.com/editorials_03/sanders030703pv.html
Shafir, Eldar, Peter Diamond, Amos Tversky, 1997, 'Money Illusion', Quarterly Journal of Economics 112 (2), 341-374.
Samuelson Paul A. 2007, 'Coeditor's Foreword, Reflections on How Biographies of Individual Scholars Can relate to a Science's Biography', in and William A. Barnett eds, 2007, *Inside the Economist's Mind, Blackwells,* USA, viii-x.
Scholes, M, 2009, Comments reported in Financial Economics: 'Efficiency and Beyond', The Economist, July 24-29, p. 71-72..
Simon, Herbert A., (1993), *Models of My Life*, Basic Books, USA.
Sordi, Serena and Alessandro Vercelli (2003) "Financial Fragility and Economic Fluctuations: Numerical Simulations and Policy Implications," Quaderni Del Dipatimento Di Economia Politica, Siena, Ottobre 2003.

Soros, George, 1987, 1994, 2003, *The Alchemy of Finance*, The Institute of Advanced Studies Princeton University lecture series with extensions, John Wiley & Sons, Hoboken New Jersey.
Soros, George, 2008, 2009 (2nd Edition), *The New Paradigm for Financial Markets: The Credit Crisis of 2008 and What it Means*, 2nd Edition, Public Affairs, US.
Smits, 1997, The European Central Bank, Kluwer Law International.
Stanczyk (2009) "Gold/Silver Ratio Chart 1999 to 2009," http://www.bestwaytoinvest.com/stories/goldsilver-ratio-chart-1999-2009
Taylor, Mark P. and Hellen Allen, 1992, "The use of technical analysis in the foreign exchange market," *Journal of International Money and Finance* 11(3), 304-14.
Telser, Lester G. (2007a) "The Fed's Real Job," *The Economists' Voice*: 4(4), Article 4. Available at: http://www.bepress.com/ev/vol4/iss4/art4
Telser, Lester G. (2007b), "Solvency vs Competition: Hobson's Choice for the Fed," *Journal of International Money and Finance*, 26, (7), 1151-1173.
Tirole, Jean (2009) Financial Crisis: Regulation, Liquidity, Provision and Crisis Management, Manchot Lecture Bonn University, February 12, 2009. Video accessible online : Part 1 http://www.uni-bonn.tv/podcasts/VortragTirole1.mp4/view, Part 2 http://www.uni-bonn.tv/podcasts/VortragTirolel2.mp4/viewAccessed July 31, 2009.
US Federal Reserve Board of Governors
September 18, 2008 Coordinated measures with Bank of Canada, Bank of England, ECB, Bank of Japan, and Swiss National Bank
September 24, 2008 Arrangements with Reserve Bank of Australia, Danmarks Nationalbank, Norges Bank, and Sveriges Riksbank
September 26, 2008 Federal Reserve and other central banks announce operations to address funding pressures over quarter end
September 29, 2008 Federal Reserve and other central banks announce further coordinated actions to expand significantly the capacity to provide U.S. dollar liquidity
October 13, 2008 Federal Reserve and other central banks announce further measures to provide broad access to liquidity and funding to financial institutions
October 14, 2008 FOMC authorizes an increase in the size of its temporary reciprocal currency arrangement with the Bank of Japan
October 28, 2008 Federal Reserve and Reserve Bank of New Zealand announce the establishment of temporary reciprocal currency arrangement
October 28, 2008 Federal Reserve, Banco Central do Brasil, Banco de Mexico, Bank of Korea, and Monetary Authority of Singapore announce the establishment of temporary reciprocal currency arrangements http://www.federalreserve.gov/newsevents/press/monetary/2008monetary.htm
Wagstyl, Stefan. (2008). "Lending fears may freeze the system," *Financial Times* (Poland), December 9, p. 6.
Westerhoff, Frank and Stefan Reitz (2003) "Nonlinearities and cyclical behavior: The role of chartists and fundamentalists," *Studies in Nonlinear Dynamics & Econometrics,* Berkeley Electronic Press, 7(4), 1125-1125
Zellner, Arnold, 1971, An Introduction to Bayesian Inference in Econometrics, John Wiley and Sons, New York.

Appendix: The Statistical Tests

A1 The One-sided Direction of Change in the Exchange Rate

The null hypothesis is that any deviation of the final 20th round exchange rate from the inertia attractor of the initial exchange rate is random, and hence is equally likely to be in either direction. The alternative hypothesis is that any deviation from inertia is in the downward direction since due to the attractor of the nominal equality 1:1 exchange rate. Hence the test is one-sided.

We counted how often (0 of 9 times) the final exchange rate was higher than the initial one of 1.4. On a binomial exact test, if the null were correct, this probability is utterly remote, namely 0.001953.

A2 Polarisation in the Exchange Rate

Divide the distance between the two attractors, the initial exchange rate of 1.4 and the nominal equality exchange rate attractor of 1:1, into four segments. Then the two middle segments comprise exchange rates between 1.1 and 1.3. Polarisation is measured by the exchange rate by the final 20th

round lying outside the two middle segments. The null hypothesis is that the extent of polarization in the population is independent of transparency concerning central bank exchange rate aims – ie that sessions labelled 1-6 and those labelled 7-9 in Table 3 are homogenous a regards polarization. The alternative hypothesis is that nominalism in the form being attracted more strongly to either one of these two attractors increases in the more complex situation of a lack of transparency concerning the two central banks' exchange rate aims. Hence the test is one-sided. On a Fisher's exact test, the probability that the two sets of sessions are homogenous as regards the extent of polarization is 0.04761905. We computed this as follows.

We constructed the following 2x2 table:

a b
c d

where

a = the number of observations among the first 6 observations for which the final exchange rate lies in [1.1;1.3] = 5

b = the number of observations among the first 6 observations for which the final exchange rate doesn't lie in [1.1;1.3] = 1

c = the number of observations among the last 3 observations for which the final exchange rate lies in [1.1;1.3] = 0

d = the number of observations among the last 3 observations for which the final exchange rate doesn't lie in [1.1;1.3] = 3

Then we calculated the significance level as:

p = [(a+b)!(c+d)!(a+c)!(b+d)!] / [a!b!c!d!n!]
= [(5+1)! (3+0)! (5+0) ! (1+3)!] / [5!1!0!3!9!]
= (6!3!5!4!) / (5!1!0!3!9!)
= (6!4!) / 9!
= 24 /504
= 0.04761905.