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

Robin Pope,1 Reinhard Selten,2 Sebastian Kube,3 Johannes Kaiser,2 Jürgen von Hagen4

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 Max Planck Institute for Public Goods, Bonn
4 Institute for International Economics, Bonn University

Abstract
This paper, a sequel to Pope et al (2008b) shows three things in how scientists and practitioners analyse and evaluate to decide (conclude). First economists unwittingly employ nominalist heuristics, defined as a focus on prominent numbers, indices or ratios feature in constructing theories (eg the purchasing power and interest parity models), to predict exchange rates and to advocate floating exchange rates. 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 procedure can involve systematic mistakes, the overall decision situation is nevertheless sufficiently simple: a) for economists and psychologists to identify what is a mistake, and b) to be compatible with maximisation. But in the typical complex situation giving rise to nominalist heuristics neither a) nor b) hold, so that 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.

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.

JEL Classification   D800, D810, F310, F330

1 Introduction
This paper examines the role of prominent numbers in exchange rate determination through SKAT, the Stages of Knowledge Ahead Theory, Pope (1983), Pope et al (2006), Pope et al (2008a). SKAT delineates the four 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 their available alternatives. Once alternatives are ascertained, the chooser has a change in knowledge ahead as he now knows its alternatives. He enters stage 2 of evaluating its alternatives. Once he has evaluated, he has his second major change in knowledge ahead, it now knows its choice. He has entered stage 3, that of awaiting to learn the final outcome segment of its chosen alternative. This stage ends with a further change in knowledge ahead. He has entered stage 4 wherein it knows the outcome of its choice, so that in this respect all risk and uncertainty is resolved – certainty reigns.

Stage 2, the evaluation of alternatives, is ignored entirely in EUT, axiomatised expected utility theory, which assumes that the evaluations are so trivially easy to do perfectly that

* 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 programmed and conducted by Johannes Leitner and 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 was developed by Robin Pope who also wrote the paper and the revision. Reinhard Selten, Johannes Leitner and Sebastian Kube contributed extensively to improving the paper and the articulation of nominalist heuristics, and Reinhard Selten also contributed to improving the revision.

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choosers costlessly maximise in reaching a choice. The evaluation stage is considered in work 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 the scientist can infer that he can identify mistakes made by others and what is the optimal decision.

In most real world situations there is too much complexity for anybody to do the stage 2 evaluation by calculating what is optimal. Concerning choice of food and music, this incapacity of everyone (including scientists) to maximise is illustrated in the fairytale in Simon (1993). When doing stage 2 evaluations in even more complex situations involving exchange rate determination, this paper will show that economists, psychologists, central bankers, firms and others, resort to prominent numbers, indices and ratios.

To identify how scientists and economic agents do their stage 2 evaluations in real world complex situations (where nobody can maximize) requires two things:

a) a new theoretical entity, namely the concept of nominalist heuristics including prominent number ratios; and

b) abandonment of standard purchasing power parity and interest parity models and indeed all maximising models within the umbrella of EUT, expected utility theory, or CPT, cumulative prospect theory so as to model within a new umbrella theory, SKAT.

The prior paper in this sequel, Pope et al (2008b) furnishes background on the theoretical constructs underlying a) and b). This paper furnishes the field and laboratory evidence concerning nominalist heuristics in one application, namely prominent number ratios in determining the exchange rate.

The paper’s layout is as follows. Part 2 comprises field evidence of the problems that economists, central bankers and firms encounter under real world complexity in predicting the exchange rate – something that they need to predict in order to perform stage 2 and evaluate their alternatives. Part 3 traces how the complex situation causes scientists and economic agents alike to resort to nominalist heuristics in predicting exchange rates and in taking other decisions on the basis of their decisions. It amasses from secondary sources field evidence of the endemic usage of prominent numbers, indices and ratios by economists in modeling exchange rates, and by public officials and private agents operating in exchange rate markets. Parts 4 and 5 furnish parallel laboratory evidence of the decisive role of a prominent ratio in exchange rate determination. Part 6 provides an executive summary and indicates ways of incorporating these nominalist effects into qualitative and quantitative investigations of the exchange rate process.

2 Difficulties in Stage 2 – in Predicting the Exchange Rate

Consider a firm who has to pay for an imported item in a foreign currency in the future, and has ascertained that it has broad classes of alternatives of: 1) doing nothing, 2) hedging against the risk that its own currency will depreciate; and 3) speculating that its own currency will appreciate prior to the import bill falling due. How should our firm perform its stage 2
evaluation of alternatives when this involves seeking to probabilistically or in some other manner predict the pertinent exchange rate? We devote this entire part of the paper to this issue. That is, Part 2 is devoted to illustrating the difficulties of such a firm, and thus any chooser – whether an academic economist, a government, a central bank, another firm or an individual – in making an exchange rate prediction. In conjunction with Part 3 below, this part of our paper constitutes our field evidence of something startling and contrary to most economic modelling and estimation of the exchange rate. This is that in doing any stage 2 evaluation that involves exchange rate prediction, academic economists and men of affairs – business economists, central bankers, treasury officials and private speculators – are all in the same boat. None can maximise. All use short cut heuristics. Many academics and many men of affairs resort to use of prominent numbers, indices and ratios.

The field evidence presented below comprises: a) a literature survey of economists' usage of short cut heuristics in the form of prominent numbers, indices and ratios in their purchasing power and interest parity models of the exchange rate; b) self-reports of central bankers and speculators on their inability to predict exchange rates when they need to do this for good macroeconomic management or firm survival; c) firms going into receivership through their inability to predict exchange rates

2.1 Academic Economists

Let us begin with how academics predict the exchange rate in order to perform stage 2. This part of our field evidence takes the form of enough of a literature survey of their exchange rate models to delineate key aspects of how academics perform this task. 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 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).

Economists now admit that their "fundamentals" equations have low forecasting power and perform badly out of sample, Engel et al (2007). Economists take comfort in the matter that for some models for some countries at a 4-year horizon, out of sample they beat the random walk, Engel et al (2007). Indeed Pagan (oral discussion) argues that fundamentals only concern long term relationships, as when each exchange rate value and each determinate is an aggregation of events over a two to four year period. Other economists uphold the unpredictability as evidence of how efficient and operative under rational expectations is the market, Engel et al (2007).

It is however essential to underline the fact that even for those practical men of affairs who agree with the above verdicts of economists' predictions not being too bad, this level of prediction does not suffice for our firm to perform its stage 2 evaluation. It means that academic economists are of minimal aid to our firm in doing its stage 2 evaluation. In order to appreciate this, consider our firm's set of three broad alternatives, to do nothing, hedge or speculate. Consider all the timing and amount details required to evaluate and choose to do a
particular act of hedging or speculating, when for each there are numerous issues to be clarified with creditors. Note that our firm is like many firms: it would go broke were it to hedge based on the expected future exchange rate in the next stage of knowledge ahead, and it later turned out that the actual exchange rate moved sufficiently far in the opposite direction to its expectation. Note that we have numerous historical experiences of this happening. It happened on a grand scale in the early 1980s as discussed in section 2.1.3 below, and as discussed in section 2.3, like ruins occur in this millennium.

To reiterate, the viability of our firm is at risk unless the point estimate of the exchange rate expectation is close to what at a later stage our firm learns is the actual exchange rate when its import bill falls due. Economists cannot offer this predictability. Economists often aver that unpredictability is virtually costless since full hedging against a depreciation is virtually costless. Such however is not the case.

Hedging is costly, especially for substantial periods ahead where it requires legal assistance to construct the contracts and thus is only available to large firms, McKinnon (2005). Further, where a firm hedges when retrospectively it would have done better to speculate since its currency appreciated, its financial viability can be lost. This is a danger if competitors speculated and as a consequence can sell the imported goods to their customers more cheaply than can our firm. In short, predicting the exchange rate is vital to the financial health of firms importing goods, as is our firm.

It is important to investigate the field evidence on how in their models economists actually do these predictions needed by importing firms in stage 2. Many economists assume that agents conform to expected utility theory in making decisions. These same economists however patently do not themselves conform. Expected utility theory postulates the stage 2 evaluations to be mysteriously known without thought. Economists by contrast put vast effort into their stage 2 evaluations, spending years with teams of research assistants trying to improve on either the algebra or the econometrics of their own and others' prior predictions. Here it suffices for our purposes to outline a couple of the main models economists employ in their arduous stage 2 evaluations.

2.1.1 Purchasing Power Parity Models
Realistically complex models, such as ones in which land is a fixed and relatively more important input into some goods in some countries, reveal that purchasing power parity would not set exchange rates even in long run equilibrium. Ie to model exchange rates as a function of some inter-country overall price ratio is to abstract, simplify, and focus on one prominent ratio that ignores (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, import price indices, export price indices. Within each category, there are numerous sub-categories of items whose prices move disparately. Exports for instance in the case of Australia comprise commodities as currently the most important followed by education. In the six months ending October 2008, commodities prices have plummeted to under a quarter of those prevailing six months ago, whiles that for education has remained in effect constant.
Such disparate price movements lie outside most academic modeling. In those theoretical and econometric studies premised on purchasing power parity, essentially arbitrarily, one of these various price indices is taken as the prominent index and designated to be "the" price level in that country and then a short-cut heuristic is employed. The short-cut heuristic is to ignore the fact that all the other prices 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 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.

Nevertheless, purchasing power parity is a lynchpin in numerous economists' exchange rate predictions and thus of their stage 2 evaluations. It is a lynchpin despite its exceedingly modest explanatory power, predicting for some countries worse than a random walk – even with panel data and considering only a horizon irrelevantly long for most firm and official sector decisions, Harris, Leybourne and McCabe (2005), Murray and Papell (2005), Engel et al (2007). It is easy to ridicule the purchasing power parity prominent ratio heuristic.

But as shown below, we cannot classify use of the prominent ratio underlying purchasing power models as a mistake in the way that we classify people as having made a mistake if in calculating how much inflation has occurred, they overweight frequently bought items. In reaching a decision on how much inflation has occurred, there are areas of controversy, such as whether weights should be of a Paasche or a Laspeyres nature, but also areas of effectively no controversy. Since essentially every economist and psychologist agrees that inflation should weight items according to some welfare criteria such as expenditure per month on that item, there is no space in the inflation index concept for frequency of purchase per month to affect the number estimated, and no dissent amongst experts on this issue. When as in Brachinger (2006), frequency is indicated to have entered how the general public estimate the inflation rate, experts agree that the general public has made a mistake.

By contrast, what actually causes exchange rates is complex, resulting in a lack of agreement among experts on how to predict them. The complexity yields scope for different economists to use different stage 2 evaluation methods, and for it to be controversial to diagnose some models (stage 2 evaluation methods) as inferior, let alone as mistakes. Some economists reject every submitted paper that they referee that uses the purchasing power parity theory on the grounds that it is theoretically unsound and empirically disproven. Other economists, eg Engel et al (2007) see purchasing power models as foundational, and better on both theoretical and empirical grounds than some others that they canvas, such as Taylor rules. In short, economists do not agree on whether the short-cut prominent ratio heuristic that lies at the heart of the purchasing power parity modelling is good, or bad. One thing however is clear. No economist employing this short-cut prominence heuristic to make decisions should claim to be proffering rational maximising predictions, but rather admit that the predictions are derived from an ad hoc short-cut heuristic.
2.1.2 Interest Parity – No Arbitrage – Models

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 US sub-prime mortgage crisis. In some countries, central bank discount rates have dropped steeply while a prominent index in the form of one particular interest rate for the specific duration is in theoretical and empirical work selected as a short-cut heuristic. The disparate levels and movements of the other interest rates are ignored. As cited in Isard (1996), Keynes found some evidence of banks using interest parity equations in setting their forward rates. Is there like evidence for the post Bretton Woods era?

Econometrics can only be successful in eras when postulated explanators exhibit enough variation. Such a period is the 1980s, when in a span of three years, 1982-5, US interest rates about doubled, and then in about the next two years, almost reverted to where they were before. For earlier and later periods when the variation is modest, the interest parity theory often did not seem disproven, merely to have minimal explanatory power, Engel et al (2007). But for virtually every country, interest parity models that include periods like the 1980s in which the interest rates change enough to render the estimated coefficients reliable, have systematically and highly significantly, wrong signed coefficients, Rapp and Sharma (1999), Bissoondeal et al (2008). As Keynes himself proposed, many other factors besides these four prominent indices in reality set the exchange rate, including exchange rate risk. In a like vein Engel et al (2006) propose that a problem with the interest parity theory is that it omits exchange rate risk.

2.1.3 Rational Expectations Efficient Markets View

There is widespread support for the view that the almost total failure of economists to predict exchange rates is because exchange rates are set in efficient markets in the sense of Fama (1965) or under so-called rational expectations of Lucas (1976). According to such models numerous EUT competitive profit maximizers use all available information in an efficient manner, and apply it to exchange rate markets. It has led some to contend that it is futile to attempt exchange rate predictions beyond accepting what the market gives as the forward rates, since these markets are efficient, eg Hu (1999), and that findings of inefficiency stem from using inappropriate tests, eg Wang and Jones (2002).
One quandary for this viewpoint is the systematic and highly significantly wrongly signed parameter estimate in interest parity models whenever the variation has sufficed to get sharp coefficient estimates. An efficient market ought operate to eliminate not exaggerate arbitrage opportunities. Further it takes a vast amount of ingenuity to say that the market is efficient and expectations rational when for over five years on end in the early 1980s, exchange rate expectations in highly regarded sources moved every quarter in the wrong direction. Specifically, from 1981 to 1984 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 between 1982 and 1985. For further details on this five year era of systematic enduring erroneous exchange rate expectations, see eg Frankel and Froot (1987).

A third quandary is that the Fama concept of market efficiency is not a concept of the exchange rate simply being unpredictable. The Fama concept is an outcome of “rational” maximization of expected profits generated in the form of an equilibrium by a sufficient number of EUT agents. In turn this means that any contention that the exchange rate market is efficient is bedeviled by the question of what is the equilibrium that the market so efficiently hovers around, Levich (1989). The implausibility that equilibrium would be stable or unique given the negative findings with regard to other neoclassical, rational expectations and so forth modelling. See 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).

The fourth quandary is what Phelps (1999) calls the farcical aspect of rational expectations. It is by today generally admitted that people do not instantly know the equilibrium. Instead it is proposed that they can learn it. But what, Phelps observes, are they to learn, when each economist has a distinct model. Whose model should they be learning?

2.1.4 Market Power

There is in addition to these four quandaries an overwhelming objection to such a Fama-Lucas world, and indeed to any other exchange rate theory embedding purchasing power or interest parity within a competitive market structure. This is the matter raised by Merton (2001) and Soros (1987, 1994, 2003), the matter of market power of key speculators. The so-called rational expectations competitive market models of exchange rates are irrational in ignoring it. Merton attributes Long Term Capital Management's difficulties to a failure to understand this hedge fund's massive market power in its Black Scholes arbitrage opportunities formulae.

There are moreover participants with even more market power than private participants. These are the pair of official sectors who issue the pair of currencies. By law under full cooperation the two official sectors fully determine the exchange rate. In modelling to predict exchange rates (and so perform stage 2 of evaluating alternatives), most economists’ short-cut heuristics ignore both (i) the market power of major speculators and central banks, and the
(iii) overwhelming power of the official sectors when fully cooperating. An important exception in allowing for official sector market power by offering a game theoretic treatment in a model comprising international agencies as well as central banks is Hausken and Plumber (2002). They offer 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.

2.1.5 Summary
In performing stage 2 evaluations, then, typically economists have found it too difficult to incorporate key issues like market power. They have found it too difficult even after the economics profession has jointly invested over 35 years, and the entire academic careers of innumerable economists in the endeavour. Models are rife with prominent indices and ratios as short-cut heuristics for complex reality. The short-cut heuristics however have not afforded economists predictions that have enough reliability to put our firm in the ball park of being confident that when it evaluates its alternatives, its mistakes will not be so big as to leave it bankrupt. Nevertheless some academic economists continue to use the terms of an “overvalued” and “undervalued” currency to describe some theoretical equilibrium whose short to medium run particulars are yet to be discovered. Others have altered the denotation of these words to reflect the academic economist's failure to establish robustly details of equilibria and at times implicitly define these terms simply with respect to where the exchange rate had established itself for some earlier period, eg Cobham (2006).

2.2 Men of Affairs
Let us now consider whether predicting exchange rates and doing stage 2 of evaluating alternatives has proven easier for practitioners. Here our field evidence of their massive difficulties has two strands, 1) accounts of central banks and speculators 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.

2.2.1 Business Economists
After any sizable exchange rate change, many business economists speak of the change as correcting an over or undervaluation. Ie they use the language of “fundamentals” and connote that the sizable change was something that they had predicted. Occasionally a journalist writes up the success record of a business economist who professes to understand the fundamentals and to use them in predicting exchange rates: it is shocking, worse than a random walk. But then such surveys cover less than a handful of business economists’ predictions, and one cannot be certain that the analysis was representative of even these business economists. Perhaps if one had full access to all their predictions, one might discover that the business economist made other predictions, omitted from the journalist’s analysis, ones that showed the particular business economist more often correct.
2.2.2 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 7 exchange rate predictions and investment strategies. A comparison is not made with the random walk, but with the S&P 500. It is contended that the exchange rate dependent investments exceed this by a factor of 6 or 7 to 1, when employed out of sample. This is exceedingly impressive, even if not results that our firm 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 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.

2.2.3 Technical Analysts
A growing proportion of exchange rate dealer firms ignore fundamentals and sell predictions based instead on what has come to be termed technical analysis. This 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. Short range predictions based on some variants of 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. Some do on average beat the random walk for horizons of a few hours to a few days ahead Moreover the hurdle is higher than barely beating the random walk. The public sector and firms engaged in real and financial imports and exports require models yielding a far higher level of predictability than this if they are to efficiently plan, and avoid massive losses - and a far longer time horizon than that for which technical analysis has attractive properties.¹

¹ 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 to few scientists with a mutual respect of both approaches to invest the effort in making such a statistical comparison.
2.2.4 Firm Failures

Firms also have access to confidential exchange rate models. 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, McKinnon (2005). 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 misprediction of the Ruble-USD exchange rate.2

2.3.5 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 was not a one-off problem of the Bank of England, rather an enduring problem 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 1996-8, then dipped, and why it had another dip in 2003, Cobham

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2 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).
Paul Volcker, former Chair of the US Federal Reserve System, finds the unpredictability even by 2001, a ground for abandoning floats.\footnote{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.}

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.

In summary, the matter of evaluating alternatives in a choice set, where the evaluation involves prediction of future exchange rates, is non-trivial. 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 stemming from faulty exchange rate predictions.

3 Field Evidence of Nominalism in Exchange Rate Determinations

The situations detailed above are too complex for anybody to maximise when doing their evaluation of alternatives involving exchange rate predictions. In this complexity, we present below field evidence that economic agents whose decisions enter exchange rate determination resort to prominent numbers, indices and ratios. The field evidence has a foreign quality to a statistically trained economist or psychologist. This is because it consists in describing how / why a particular prominent number, index or ratio sets the exchange rate. The reasons may seem bizarre and anecdotal. Their seeming bizarre and anecdotal however is not the issue. The issue is the evidence that these prominent numbers, indices and ratios influence, even to the point of a prominent ratio often completely and exclusively determining, an exchange rate.

3.1 Exchange Rate Contracts

Nominalism enters exchange rate determination through the tendency to write international debt contracts in nominal exchange rate terms. Such nominalist 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 should influence the exchange rate contract terms. (Economic modelling nearly always is only one step less nominalist – it tends to consider only the subsequent exchange rate cum price level of a pair of countries.)

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 number ratios and other connections between numbers. Many economists and others laugh at usage of such techniques, so that whiles they must have some impact on exchange rates, the over impact may be modest.

But when understandings are reasonably widespread, their impact on exchange rate can be decisive. We give but one example. Two widely used currencies in antiquity were gold and silver. The exchange rate of gold to silver remained for centuries roughly 13:1. This 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. This could be maintained for extended periods given the fiduciary role of any currency, and by many trusting / believing in the ratio of 13:1 being the natural harmony – the equilibrium. This prominent ratio of 13:1 has been the most enduring and decisive exchange rate determinant in the world, present already in ancient Greece. On the discovery of the new world, other gold to silver exchange rates emerged across the Atlantic, aiding in the ending of that ratio also in Europe.

Prominent number ratios did not disappear from exchange rates with modern astronomy. Nor did they disappear with strains on the bimetallic gold-silver currency system due to massive new mineral discoveries altering their relative costs of production more than marginally. One continuing form of prominent number ratios is historical benchmarking.

3.4 Historical Benchmarking
Prominent numbers have been interpreted as determining whether an exchange rate 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 (1971-88), Howson (1975), Earley (1976), Pope D and Pope R (1980), and Butkiewicz (2005a, 2005b). 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. Recently China settled on maintaining a historical benchmark of the Yuan to the USD, and only after extreme US and EU pressure recently weakened this.

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 blow 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.

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 when the Euro initially slid below 1:1 with the US dollar, and when it later rose above that nominal equality of 1:1. 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). From 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. Thus relatedly she found some statistical support for the predictions furnished by this set of chartists / technical analysts on what sets exchange rates.

Osler's findings, however, like the media reports that abound in prominent numbers, 4 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.

4 On 19 May 2008 for instance, the below google web link has two pages of prominent ratios of exchange rate forecasts for the Australian dollar forecast to reach 1:1 with the USD, of prominent number 1.6:1 of the EUR/USD rate having been attained, and of other prominent ratios via historical benchmarking concerning when these currencies had turning points against various other currencies.

file:///Users/robin/Documents/Files/transfer%20files/papers%20rec’d%20gen%2021%20jul06/aus%20dollara
r%20high
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 bedeviled 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 et al (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. 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 and the UK Treasury refused to raise its interest rate to stave off the attack, while the German central bank refused to intervene to rescue the pound, forcing the UK to quit the process leading to being a member of the planned EURO. An example of adequate central bank cooperation was when France suffered a speculative attack in 1993. While the
French central bank did not raise interest rates to keep parity with the DM, Germany’s central bank intervened sufficiently to avoid so large a depreciation of the French Franc that the rules could not be doctored and France permitted to stay in the process leading to the planned EURO.

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, $\xi_1$, of its export price 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, $\xi_2$, of its import price 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), $\xi_1 > \xi_2$. 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, say so 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 them in New Zealand, Robin Pope (2007a, 2007b)) called for that capital gains tax and a like one on other assets 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 the enforcement of the US Federal Reserve’s commercial bank reserve ratio requirements and for capacity-to-repay constraints on mortgages issued.

Our limiting the official sector to four instruments when tasked with seven objectives is likely in the right ball park 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 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 the 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 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.

The objectives-instruments details of our set up are as follows. 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 prices steady; 2) meeting its 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 were as in Table 5, including the real life issue of a higher penalty for too little employment than for too much.
Table 5: Official Sector Objectives

<table>
<thead>
<tr>
<th>Variables</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$q$</td>
<td>actual price of the home country consumption good</td>
</tr>
<tr>
<td>$p_{t+1}$</td>
<td>next period’s target price of consumption good</td>
</tr>
<tr>
<td>$p_t$</td>
<td>current period’s target price of consumption good</td>
</tr>
<tr>
<td>$e$</td>
<td>exchange rate, the number of unit of home currency needed to buy one unit of</td>
</tr>
<tr>
<td></td>
<td>foreign currency, and thus as $e$ rises, the home currency depreciates</td>
</tr>
<tr>
<td>$m$</td>
<td>actual price of home materials in home currency</td>
</tr>
<tr>
<td>$m^*$</td>
<td>actual price of foreign materials in foreign currency</td>
</tr>
<tr>
<td>$r$</td>
<td>interest factor ($1 + $r$ = marginal interest rate)</td>
</tr>
<tr>
<td>$f$</td>
<td>exchange rate aim</td>
</tr>
<tr>
<td>$B$</td>
<td>official sector (government and central bank) objective function</td>
</tr>
<tr>
<td>$L$</td>
<td>actual employment</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r_0$</td>
<td>ideal interest rate, set at 0.05</td>
</tr>
<tr>
<td>$L_a$</td>
<td>minimal acceptable employment, set at 600</td>
</tr>
<tr>
<td>$L_b$</td>
<td>maximum acceptable employment, set at 720</td>
</tr>
<tr>
<td>$b_i$</td>
<td>weight parameters, $i = 1..5$. The $b_i$ are positive constants, set respectively as 6, 6, 3, 3, 0.02 and 0.01</td>
</tr>
</tbody>
</table>

Official Sector Objective function

$$B = b_0 - b_1 \left( \frac{p_{t+1}}{p_t} - 1 \right)^2 - b_2 \left( \frac{d}{p_t} - 1 \right)^2 - b_3 (r - r_0)^2 - b_4 \left( \frac{m}{em^*} - 1 \right)^2 - b_5 \left( \frac{e}{f} - 1 \right)^2$$

$$- b_6 \max\{L_a - L, 0\} - b_7 \max\{L - L_b, 0\}$$

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 profits flowing to the firm’s owners.
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 some 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 6, where all exchange rates are expressed from the perspective of country A, ie as beginning at 1.4.
Table 6
Exchange Rate Progression toward 1:1

<table>
<thead>
<tr>
<th>Session</th>
<th>Public Knowledge</th>
<th>Known only in the Official Sectors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Start in equilibrium</td>
<td>1.4</td>
<td>1.4</td>
</tr>
<tr>
<td>20 periods later</td>
<td>1.2</td>
<td>1.14</td>
</tr>
</tbody>
</table>

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.

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 forthcoming. 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?
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. Either 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 alternative 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). 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. One however 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 now 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. The sub-prime crisis in due course ushered in discussion of another prominent ratio, that of 1:1.5. As that crisis further unfolds with a need to return funds to the US, another prominent ratio has emerged in the media of 1: 1.25. The importance of such prominent ratios might be checked by ascertaining whether adding such terms enhances the explanatory power of equations during the periods in which each ratio was prominent in the media.

References


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?


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 labeled 1-6 and those labeled 7-9 in Table 6 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:

\[
\begin{array}{cc}
\text{a} & \text{b} \\
\text{c} & \text{d}
\end{array}
\]

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:

\[
p = \frac{\text{a}! \text{b}! \text{c}! \text{d}! (\text{a+c})!(\text{b+d})!}{\text{a}!\text{b}!\text{c}!\text{d}!n!}
\]

\[
= \frac{(5+1)! (3+0)! (5+0)! (1+3)!}{5!1!0!3!9!}
\]

\[
= \frac{(6!3!5!4!)}{(5!1!0!3!9!)}
\]

\[
= \frac{24}{504}
\]

\[
= 0.04761905.
\]