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The Underlying Cause of Unpredictability in Exchange Rates and Good Models of Exchange Rate Regime Selection: Field and Laboratory Evidence

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BONN ECON DISCUSSION PAPERS

Discussion Paper 27/2006

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December 2006



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The Underlying Cause of Unpredictability in Exchange Rates and Good Models of Exchange Rate Regime Selection: Field and Laboratory Evidence[†]

by

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Abstract

Variance of exchange rates around predictions can be from 1) undiscovered fundamentals, 2) efficient markets, 3) destabilising speculation, or 4) regime and personality differences in the heuristics used in the stage of evaluating alternatives. Field and experimental evidence identifies 4) as the underlying cause. Variance effects prior to the resolution of risk damage macroeconomic management but are excluded by expected utility theory wherein utilities attach only to the segment of the outcome flow after risk is passed. To include the evaluation stage and such damage from variance, the authorities can use models within SKAT, the Stages of Knowledge Ahead Theory.

Key words exchange rate regime, exchange rate unpredictability, experiment, SKAT the Stages of Knowledge Ahead Theory, variance, outlier analysis, group dynamics, individual differences.

JEL Classification D80, D81, F31, F33

[†] We thank for funding the German National Science Foundation. We thank for helpful discussions or comments on our experimental set-up David Cobham, Heriot-Watt University, David Cook, Hong Kong University of Science and Technology, Dan Friedman, University of California, Santa Cruz, Kjell Hausken, University of Stavanger, Mike Gilroy, University of Paderborn, Peter Kenen, Princeton University, Angelo Sanchez, European Central Bank and others at conference and workshop presentations. We thank Kerstin Wandschneider for background information; thank for statistical assistance for Sebastian Kube, thank for research assistance Angela Meyer, Shiraz Ahmed, Bonn University and Daniel Lederer, St Andrews University

Thursday, December 14, 2006

The Underlying Cause of Unpredictability in Exchange Rates and the Appropriate Exchange Rate Regime: Field and Laboratory Evidence[†]

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Variance of exchange rates around predictions can be from 1) undiscovered fundamentals, 2) efficient markets, 3) destabilising speculation, or 4) regime and personality differences in the heuristics used in the stage of evaluating alternatives. Field and experimental evidence identifies 4) as the underlying cause. Variance effects prior to the resolution of risk damage macroeconomic management but are excluded by expected utility theory wherein utilities attach only to the segment of the outcome flow after risk is passed. To include the evaluation stage and such damage from variance, the authorities can use models within SKAT, the Stages of Knowledge Ahead Theory.

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This paper is concerned with the underlying cause of exchange rate unpredictability, and with the means of choosing an exchange rate regime that takes into account how this damages macroeconomic management. Parts 1 to 6 detail the unpredictability, and test four hypotheses of its underlying cause:

- 1) ignorance of the fundamentals;
- 2) randomness via efficient markets;
- 3) destabilising speculators; and
- 4) differences of personality, evaluation heuristics, and the institutional and cultural environment of officials interactively determining the exchange rate regime.

Field and experimental findings decisively refute 1), 2) and 3), decisively corroborate 4).

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Whether choice of exchange rate regime should be influenced by the unpredictability depends in part on whether unpredictability damages macroeconomic management. In Part 7, section 7.1 provides experimental evidence, while section 7.2 provides from field instances of massive massive damage. Parts 8 and 9 show that the limited theoretical and empirical research on the damage stems from data problems, tractability difficulties, the borderless theoretical perspective as regards capital flows, and the use of EUT, axiomatised expected utility theory. Part 10 introduces SKAT, the Stages of Knowledge Ahead Theory so as to consistently analyse and estimate unpredictability effects and choose an appropriate exchange rate regime.

1 The Unpredictability

There has been some success in describing the intra-day volatility pattern of exchange rates, Andersen and Bollerslev (1998) and Andersen, Bollerslev, Diebold and Lays (2000). There has also been some success in predicting exchange rates up to a few days in advance via certain technical analysis methods. Such technical analysis methods involve attention to prominent number ratios, Neely (1997), Osler (2000, 2003).

But for trade and its associated capital flows, the day in advance for which the exchange rate needs to be predicted is far longer than an hour or a day or a week in advance. It is of the order of a year plus, Pope (1981, 1985a, 1987). For such longer horizons, economists do often manage to predict out of sample better than a random walk, but not markedly better – and not with predictions accurate for the specific short durations within which import bills and interest repayments fall due. Rather the out of sample superiority over the random walk is only when the daily exchange rate data are averaged over very extended periods, Meese and Rogoff (1983) and Alquist and Chen (2006).

Purchasing power parity remains a lynchpin of economic theorising and estimation of the quarterly exchange rate. But even with panel data, there is evidence of it holding only conceivably if the data observations were each in the order of a time period of two plus years, and the time horizon comparably long, not when the data durations and time horizon concerns quarters, Harris, Leybourne and McCabe (2005), Murray and Papell (2005). Basic relationships between the forward and spot exchange rate are so little understood that the empirical sign is the reverse of that predicted by standard exchange rate theories, eg Levich (1989).

Relatedly the official sector finds major discrepancies between its predictions of the exchange rate and what happens. For the US official sector disappointments see Volcker

(2001) and Mehrling (2001). For the Bank of England puzzlement, see Cobham (2006). For the Treasury in Australia, see the report of the parliamentary inquiries into the massive losses on its exchange rate speculation interest rates swaps, Kohler et al (2002). For the central bank of Norway's frustrations, see Berge (2006).

2 Field Evidence on the Underlying Cause

2.1 Undiscovered Fundamentals

It could be that the official sector's inability to predict exchange rate changes comes from it not understanding exchange rate fundamentals. Once these are understood, variance of actual exchange rates about their predicted values will become minor. Those who adhere to the concept of there being exchange rate fundamentals to discover, so far as the authors are aware, use models within the expected utility theory umbrella. Under this umbrella, each agent maximises its expected utility and there is either:

- a) one representative agent for each distinct interest group of buyers and sellers of the currency in question, each whom has an identical and correct understanding of the influences that determine the exchange rate market and avoid "irrational" nonsense considerations such as the nominalism of prominent ratios for exchange rates; or
- b) a sufficient proportion of agents of type a) in each distinct interest group to set the exchange rate.

Those adhering to this fundamentals view anticipated after the demise of the Bretton Woods Agreement, minimal variance in exchange rates, Kenen (2002). Now 35 years have elapsed since the demise of the Bretton Woods agreement without economists being able to discover themselves the correct understanding itemised in a) above. Economists advise firms, central banks and Treasuries in their exchange rate management, and thus their models of fundamentals enter the exchange rate process. Economists themselves have failed to discover how the exchange rate market works.

Economists played key roles in the past on official sector understanding of exchange rates. So it could only be the case that there are such fundamentals to discover if official sectors are irrelevant to exchange rate determinations. The models of fundamentalists however are premised on central banks playing a key role. In these models, the central bank's rediscount rate (or in earlier models sometimes its money stock) plays a pivotal role. We thus can exclude the irrelevance of the official sector in exchange rate determination under a fundamentals approach. In turn this means that the field evidence is decisive that the fundamentals approach is false.

2.2 Markets are Too Efficient to Permit Better Predictions

According to this hypothesis, the massive variance of exchange rates around their predicted values arises from the exchange rate markets being perfectly efficient. There is a sufficient proportion of expected utility maximising agents amongst each distinct group of buyers and sellers – each with the identical and correct understanding of the market. The high variance is simply because the economic system itself has this large amount of randomness. According to this hypothesis, those adhering to the fundamentals approach were correct except in one detail. That detail is that they underestimated the natural amount of variance in this well functioning market dominated by rational expected utility theory maximisers. The actual variance under the efficient markets hypothesis moreover is enlarged by some tricky-to-determine extra amount. There must be a hovering about the equilibrium, not the market precisely on it to avoid some paradoxes, Grossman and Stiglitz (1980). The field evidence however rebuts the efficient markets theory in the same way that it rebuts the fundamentals approach discussed in section 1.1 above since this rebuttal did not rest on niceties in the degree of variance which is the only thing that distinguishes these two hypotheses.

2.3 Destabilising Speculators or Non-Cooperating Central Banks?

To have destabilising speculation, there needs to be an equilibrium for the speculators to destabilise. The field evidence refutes the existence of such an equilibrium with the characteristics of the expected utility maximising "rational" fundamentals approach, Part 3 above. We require an alternative concept of equilibrium. This should address the reality of power in an exchange rate market, and can be as follows. There is an equilibrium for each exchange rate, in the sense that any deviation will be small and quickly reversed, if each pair of central banks agrees on its bilateral exchange rate and fully supports holding this. This concept of equilibrium springs from a recognition that total co-operation between any pair of central banks sets with certainty the exchange rate within any reasonable time span (of a day or two). This is because:

- a) Any desired exchange rate is attainable by one of the pair of central banks selling enough of its own currency;
- b) Each central bank has unlimited power to produce and sell its own currency on this market; and
- c) The pertinent central bank requires only a short time span to ascertain by how much to sell in order to achieve the goal.

Under this notion of equilibrium – one based on incontrovertible facts, all exchange rate changes arise from less than complete cooperation among central banks. Exchange rate

changes arise out of less than complete cooperation – indeed often out of outright conflict between pairs of central banks. The current conflict hot-pot in this respect is the US effort to have China appreciate against the US dollar. Ie, speculation is *not an underlying cause* of exchange rate changes, but a *consequence of incomplete central bank cooperation* – incomplete covering the range from almost full cooperation to full conflict. To suggest that speculation is an underlying cause is to ignore the legal realities of who can issue domestic currency, and in unlimited amounts, to place on the exchange rate market.

2.4 Individual Differences

Since central banks are *the* key players in exchange rate markets, the role of the personalities who sway central bank policy, and of the institutional power structure (formal and informal via democratic and other pressures) underlie exchange rate changes – and their unpredictability. Cooperation or conflict between each pair of central banks depends on many factors. It depends on how that pair of governments feel toward each other. Feelings can change over time, even abruptly, with changes in who is at the helm in each country and the personal and political affinities so generated. Germany's friendship with France through an exchange rate crisis in the early 1990s is credited by many with enabling France's continuation in the European Monetary System that ushered in the EURO, Eichengreen and Wyplosz (1993).

Cooperation or conflict also depends on friendships or the lack thereof between central bankers themselves. Thus the gold and silver standard between France and the UK survived crises in the first half of the 19th century through bilateral central bank cooperation. The gold standard operated in the second half of the 19th century and up to the first world war largely through tri-lateral cooperation of the central banks of the UK, the Hohenzollerns and the Habsburgs. The interwar gold standard collapsed partly through lack of cooperation on the parts of the revived power of France, the newcomer to being an international powerbroker the US that at that time had isolationist tendencies. See eg Hook (2005), Butkiewicz (2005a, 2005b).

Cooperation or conflict amongst central banks additionally depends on how democratic the system is. Popular emotions matter more than a century ago when few countries had a nationalist central bank. In the 1930s, the newly created plethora of national central banks were sensitive to emotions of a beggar-thy-neighbour form. Many countries suffering depression were keen to depreciate and thereby seek to export their unemployment problem. By contrast, in the late 1960s and early 1970s, the US was in an emotional space

where it felt that depreciations should be the lot only of economically weaker countries. National pride prevented the US from reforming Bretton Woods with an increase in the price of gold, Mehrling (2001).

Cooperation or conflict amongst central banks is affected too by the extent to which each central bank conforms to the wishes of its government. Germany's central bank governor Erminger's success in undermining the German government's keenness for the EURO is seen as a factor behind Germany's central bank seeking exemption from a key clause of the Maastricht Treaty, the treaty designed to enable countries to later enter the EURO. It obtained exemption from cooperating fully with other entering countries' central banks. In turn this enabled Germany's central bank to fail to fully support the currency of a fellow Treaty member, the UK. It failed to fully support when the British pound when the pound was under attack. This inadequate intervention support is credited with the pound's severe depreciation in 1992, and the UK not remaining in the process that created the EURO, Eichengreen and Wyplosz (1993).

Cooperation or conflict among central banks moreover depends on politicians' friendships, the rules of whether the Treasury or the central bank is in control of exchange rate interventions, and the character of central bankers. Consider responses to President Reagan dramatically expanding from 1982 the US fiscal expenditures in an arms build-up that coincides with (i) the US Treasury having control of exchange rate intervention and being opposed to using this power and (ii) the Chairman of the US Federal Reserve System Paul Volcker remaining firm on a tight monetary stance in an effort to curb inflation. After this Reagan-Treasury-Volcker mix had been operating in tandem for a while, the US dollar roughly doubled in value and world interest rates rose dramatically. This was to the ruin of many a less developed country and exceedingly damaging to developed countries. Paul Volcker informs us that it was only in 1984 – after Germany's central bank did a big intervention, unaided by a coordinated inter-country intervention to reduce this spike in the dollar – that the situation changed. It changed via a friendship. Margaret Thatcher succeeded in persuading President Reagan to modify his policies, Mehrling (2001). There ensued in due course a like dramatic roughly halving of the value of the US dollar in a couple of years.

The field evidence is thus considerable on how individual differences amongst central bankers, Treasury officials, politicians, emotions of the populace in a country, and the disposition of legal powers over central bank policy and exchange rate interventions, all

enter the decisions of countries to have their central banks cooperate or conflict. These differences and their evolving interplay in group dynamics has yielded amongst the exchange rates of developed countries a doubling and a halving of exchange rates in five years.

Predicting all these individual personality and country differences and how they impact on the exchange rate is a daunting task. The minutes of central bank meetings and the memoirs of central bankers record the surprises and the disappointments in this exceedingly difficult-to-predict matter of exchange rates. There are wars of nerves as the speculators along with the central bankers, try to guess the extent to which by daring, the central bank succeeds without cooperation that might not be granted.

The UK in the First World War was close to one day of gold left for payment of imports at the end. This too could have been a precipice with extreme repercussions. If on the precipice, would the US Federal Reserve System, so uncooperative later, have pushed the UK over that precipice? Consider the cases where the dare succeeds, and the speculators have their fingers burnt, as in the case of France in the early 1990s. Consider too earlier dares. Consider the cases where the dare has failed as on Black Wednesday in September 1992, and despite the Bank of England making the dare extreme – with no fall back position for itself, Germany's central bank failed to sufficiently cooperate.

It is tricky identifying via econometric or other techniques why some dares succeeded and others failed and identifying all the other different influences on central bank degrees of cooperation and conflict and the associated responses of the private sector even ex post, for descriptive, understanding purposes. For an interesting account for three successive US Federal Board Chairmen of the common cyclical (robust out of sample) effects plus the contrasting personal impact effects on *domestic* risk premia, see Ludvigson and Ng (2006). But providing a similar account of the impact of successive central bank governors in any country on *currency* risk premia – the risk premia of direct relevance to exchange rates – however, lies, so far as that authors are aware, in the box of future research. Going yet one step further, and predicting the exchange rate effects of an incoming or not even yet elected combinations of central bankers, treasury officials and politicians, would be a very tall order.

3 A Laboratory Set-up

There is an episodic, qualitative and anecdotal element in Part 2's use of field evidence to delineate the impact of individual differences and their associated group dynamics on

whether central banks conflict or cooperate, and thus on exchange rate outcomes. Another handle on how individual differences generate group dynamics of cooperation or conflict amongst official sectors and private operators in generating the exchange rate is an experiment. Moreover if we examine experiments with non-parametric tests, these free us of from some of the difficulties that we would encounter using econometrics combined with field data to assess the impact of individual differences. Those difficulties include the questionable:

- 1) constancy assumptions concerning regression coefficients when over time or across countries or individuals much is changing;
- 2) independence assumptions as regards cross sectional and time series observations when these agents have forms of communication and thus *prima facie* interdependence;
- 3) distribution assumptions concerning errors and related exogeneity assumptions concerning some of the explanatory variables.

A laboratory experiment also frees us from imposing the assumption disproven for central bankers that each player seeks to optimize his expected utility and performs a standard game theoretic analysis of the situation. It allows agents follow an aspiration-adaptation procedure such as Selten (1998), or behaviours that are that mix of hedging and optimism detected in Kaiser and Kube (2005), and to use many other heuristics.

3.1 A Concrete Complex Setting

We make the context concrete, given the evidence that context affects decisions, eg McFadden et al (2005). 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 uncertainty, since uncertainty itself generates complexities. 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). To our knowledge it is the most complex experiment performed in an economics laboratory other than those on the Sinto market, Becker and Selten (1970), Becker, Hofer, Leopold and Selten forthcoming. More complex experiments have however been conducted in psychology laboratories on economic decision- making, eg Dörner, Kreuzig, Reither and Stäudel (1983) and MacKinnon and Wearing (1983). To grapple with real world uncertainty costs, we sought as complex a design as was teachable to advanced economics students for them to play it within a day, and also theoretically analyzable with a game theoretic benchmark.

Despite simplifications, the set-up is sufficiently complex that we are unable to spell out a standard game theoretic solution. We restricted the complexity to what was teachable to advanced economics students for them to play it within a day, and analysable with a game theoretic benchmark of an incomplete equilibrium, designed by Reinhard Selten. It involves the non-cooperative Cournot equilibrium for final output, and a Nash bargaining solution in the nominal wage rate bargaining. The incomplete equilibrium does not specify choices at all information sets. It allows a player to neglect those branches of the game that, on being reached by his actions could not improve his payoff, no matter what is assumed about unspecified choices.

3.2 The General Set-up

Our set-up has two countries, symmetric in every respect, and thus allows for big country effects of central bank cooperation or conflict. 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 domestic Cournot market, with nominal demand set by the government. Firms face fixed costs, must produce at least a minimum amount, and face a capacity constraint on the maximum that they can produce.

3.3 Credit, Interest Rate Charges and Opportunities

There is no cash, reflecting the fact that in advanced countries, only a minimal portion of firm working capital is in this form. Firms operate exclusively on credit up to their credit limit with their home and foreign bank. Firms thus face interest charges on their three inputs for producing physical output, labour, local materials and imported materials. Firms also face interest charges on their borrowings for hedging and speculative capital flows, and reap interest in the other country in which they lodge such borrowed funds. Interest is earned in the same period, and interest due must be paid in the same period. Sums on the foreign account however – debits for imported materials, and credits on capital invested abroad – only get repatriated in the next period.

Interest rates thus affect firm decisions in the standard ways. Higher interest on borrowed funds deters production and borrowing for hedging and speculation. But inter-country interest differentials entice capital flows. In their hedging or speculating in the current period, firms face uncertainty concerning both the current exchange rate, and because of the lag in the repatriation of profits on a firm's foreign account, the future exchange rate.

3.4 Exchange Rate Determination

If the two central banks have the identical aim for the exchange rate, they determine it, as in reality. In the case of central bank conflict, each central bank intervenes to support its exchange rate aim. Each bank automatically intervenes up to a set multiple, ξ_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. Each bank automatically intervenes up to a set multiple, ξ_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 in keeping it at the nearest of their two exchange rate aims. It is in the common interest of both central banks to join forces to this extent against the firms.

3.5 Official Sector Tasks and Instruments

In addition to the government setting nominal expenditure for this period, the official sector, in the form of its central bank, sets its interest rate for this period and announces its target price for next period and its exchange rate aim for this period. Between its government and central bank, a country's official sector has four instruments of macromanagement. In having only four instruments, it is, as in real life, under-instrumented for meeting its goals, here seven: 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; 7, avoiding unduly high employment). This latter goal is less important than underemployment, and accordingly is given less weight in the overall objective function. 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, and both suffer the same specific penalties for deviating from each of its goals. See Table 1.

Table 1: Official Sector Goals

<u>Variables</u>	
q	actual price of the home country consumption good
p_+	next period's goal for the price of consumption good
p	current period's goal for the 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
<u>Parameters</u>	
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, $i = 0 \dots 5$. The b_i are positive constants, set respectively as 5, 6, 6, 3, 3, 1, 0.02 and 0.01
<u>Official Sector Objective function</u>	
$B = b_0 - b_1 \left(\frac{p_+}{p} - 1 \right)^2 - b_2 \left(\frac{q}{p} - 1 \right)^2 - b_3 (r - r_0)^2 - b_4 \left(\frac{m}{em^*} - 1 \right)^2 - b_5 \left(\frac{e}{f} - 1 \right)^2$ $- b_6 \max\{L_a - L, 0\} - b_7 \max\{L - L_b, 0\}$	

3.6 Exchange Rate Targetting and Shocks

From Table 1, as in the 1961 Mundell model, official sectors can target (manipulate) exchange rates so as to re-equilibrate the economy after shocks. But we shed fresh light on the issue by dropping the Mundellian 1961 assumption of no capital flows and of there either only ever being one shock ever, or else (extended Mundell) a set of shocks produced by a random generator and in each case external to the system, as it were from outer space. In such Mundellian plus models the central bank knows perfectly the source of the shocks, knows exactly what the fundamentals are and where the new equilibrium is. We replace these false assumptions about shocks and knowledge of the new equilibrium and of the fundamentals in our laboratory experiment, by having instead all shocks generated unwittingly by the domestic official sector – and sometimes wittingly, sometimes unwittingly, by the private sector. Thus in our laboratory set-up central banks and governments can be as idiosyncratic, fallible and error-prone as has been the Bank of England in its exchange rate policy according to Cobham (1994, 2002a, 2002b, 2006). In our laboratory set-up, firms as in real life can attempt to make a profit out of exchange rate dealings if they think that one country's central bank has adopted an untenable position as regards its joint choice of exchange rate aim plus interest rate relative to the other central bank. Being also individuals and fallible, in our laboratory set-up, if firms misjudge the situation, they may lose funds on a grand scale (like Long Term Capital Management), or

on a small scale (like some British universities with overseas campuses). Out of this mix of varied personalities and group dynamics in the private and public sectors in the two countries, our experiment offers a fresh perspective on why predicting exchange rates has eluded official sectors after the breakdown of Bretton Woods.

3.7 The Private Sector

After the official sector has set its four targets and made these public knowledge, in each country the union and employer representative bargain over nominal wages. In this bargaining the union representative's payoff is real wages measured as nominal wages divided by the announced official sector target price, while that of the employer representative, is the profit of the firms deflated by nominal expenditure. If after the set time allowed of 10 minutes, an agreement had not been reached, there was strike, with both negotiators receiving zero pay. In strike periods there was an institutionally set wage, and firms are subject to a lower maximum production level and a cut in nominal demand relative to that announced by the government.

Once the wage rate (from bargaining or a strike) was announced for both countries, firms decided on output and on the amounts of a currency (home or foreign) to borrow in order to offer on the foreign exchange market in order to either hedge, speculate. In making their decisions the firms face two credit limits, one from their domestic bank and one from the foreign country's bank. Their credit limits are multiples of respectively the domestic and the foreign wage rate. Following their decisions, the currency market operated, and set the period's exchange rate, followed by the consumer market, determining the consumer price, followed by firms paying for last period's imported materials, and profits flowing to the firm's owners.

3.8 Periods, Sessions, Independence

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

The periods of a single session are interdependent, having in each successive period the same people and some common history. The first period 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 run in 2005, with the exchange rate aims known only to the two central banks. It might be thought that this yields us nine times 20 = 180 independent observations. This however is not the case since there is an interdependence among successive periods in a single session arising out of the history, something that has to be overlooked in field data, combined with some efforts to delete detected serial correlation.

We avoided any cross sectional as well as history-based interdependencies by ensuring that each of the nine sessions contained different participants. We have nine counterfactual worlds to aid us in assessing exchange rate regimes, nine independent observations. We have nine independent takes on how a constellation of agents with differing propensities to generate shocks.

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, students often reported how interesting was the experience, and how instructive in macro-international finance. This was especially the case with doctoral students. 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 students in Bonn obtain in outside casual employment, but some virtually none, and many others more than fourfold the normal rate.

4 Results

4.1 Not Fundamentals Nor Efficient Markets

As measured by e , the number of unit of home currency needed to buy one unit of foreign currency, for one country in the starting equilibrium the exchange rate was 1.4, and for the other country therefore the inverse of this, namely 0.7143. That is, if people recognized the exchange rate fundamentals and behaved as prescribed by the incomplete equilibrium solution, the exchange rate would float for all 20 periods at its initial rate of 1.4 for one country, and 0.7143 for the other.

It might be thought that the sessions were dominated by a sufficiency of expected utility theory maximisers who moved at random around the initial equilibrium or to another equilibrium determined by fundamentals. Such however was not the case. A sufficiency of players used the non-maximising heuristic of predicting that the exchange rate should move to the prominent nominal ratio of 1:1 that this was the direction in which the exchange rate shifted in all nine sessions, Table 2.

Table 2
Exchange Rate Progression toward 1:1

<i>Exchange Rate Aim</i>	<i>Public Knowledge</i>						<i>Known only in the Official Sectors</i>		
<i>Session</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>	<i>8</i>	<i>9</i>
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

In reading this table recall that the actual exchange rate is determined in the manner explained above in section 4.1 by the joint interaction of the exchange rate aims and associated interventions of the two central banks plus the offers of the two currencies made by firms for speculative and hedging activity and for payments for prior imports. In such market determination that involves the ratios of offers of the two currencies, choice of prominent numbers does not imply a prominent number for the exchange rate, which is the ratio of two sums of prominent numbers. But a focus on prominent numbers can cause this ratio, ie the exchange rate, to move in a particular direction, eg towards 1:1. On the binomial exact test statistic, the probability of this uniform decline being by chance – and not due to nominalism – is under 1%. We thus disconfirm in the laboratory both the fundamentals approach, and the efficient markets approach, both already disconfirmed by field data. Here however our disconfirmation is more systematic in that it occurs in every session, and over longer horizons than those of technical analysis. It occurs over those horizons pertinent for physical international trade and its associated capital flows.

4.2 Individual Differences

While all nine sessions exhibited the nominalism of having moved toward 1:1, the extent of the nominalism varied. Three sessions in effect attained it, those labeled sessions 6, 8 and 9. One attained of these three it precisely, one only a shade less, from 1.4 down to 1.01. One with a shade of overshooting, from 1.4 down to 0.96.

The other sessions moved toward the prominent 1:1 ratio to lesser degrees. Two moved nearly three quarters of the way to 1:1, down to 1.14 and 1.12. Three moved halfway down from 1.4 to 1.2 or just below, to 1.19. One barely moved down at all, only to 1.39.

This is a dramatic degree of variation. One third fully shifted their exchange rates by the full 40% to attain the prominent 1:1 number. The majority shifted their exchange rates by three quarters to one half of this distance to the prominent number, ie shifted their exchange rates by between 20% and 30%. An outlier session shifted only minutely in this direction. This bodes ill for prediction. It highlights the tremendous influence of individual personalities on the exchange rate process, and their interactions in a session generating idiosyncratic group effects.

The variation accords with actual exchange rate determination and the role of personalities and group dynamics. To maintain exchange rate goals, where sought in their own right or as signaling and other means of attaining domestic price / inflation targets, central bankers cannot attain it by their own monetary policy alone. Our theories based on this predict too poorly to enable this. Rather attaining an exchange rate goal depends partly on cooperation with other central banks (swaps or joint interventions). The only other alternatives for central bankers are to keep big enough foreign reserves (eg Japan and China), or limit capital flows (eg Malaysia).

4.3 Effect of Transparency in Central Bank Exchange Rate Aim

Consider now where along the spectrum from the initial game theoretic “equilibrium” of 1.4:1 to the prominent number “equilibrium” of 1:1 countries had moved by the 20th period. The transparency or otherwise of central bank exchange rate aims seems to play a role. 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 sessions 1 to 6, the exchange rate aims of the two central banks are public knowledge. Here the move from the initial game theoretic “equilibrium” of 1.4:1 to the prominent number “equilibrium” of 1:1 is typically intermediate. In five of the six sessions it lies in the middle half (1.1:1 to 1.3:1) of the range between 1.0:1 and 1.4:1. The outlier is session 6 which moved virtually the full distance to the prominent number 1:1.

The probability of the null hypothesis that the non-transparent condition derives from a population with no greater a propensity for distribution outside this middle half of the range

is under 1% on Fisher's exact two-tailed test. This hints that prominent numbers and nominalism or another rule of thumb, staying put, play an even bigger role when the complexity and thus the uncertainty of the situation rises. The matter of which rule of thumb becomes a decisive focus however appears to be idiosyncratic, unpredictable, a function of personalities and their group dynamics. Nothing else is different in the three non-transparent sessions, only the personalities.

5 Outliers and Variance Analyses

In the experimental set-up, the variation in responses in distinct sessions and outliers revealed in the experimental data bode ill for predictive power from any theory of exchange rate analysis. The very wide scatter found in our experiments mirrors the unpredictability uncovered from field data. The qualitative field evidence is of the key roles of individual institutions and personalities in making decisions in ways different from that of expected utility theory maximisers, and of how their associated group dynamics set exchange rates. The laboratory evidence reveals that the role of individual personalities and fine details of regime distinctions is pervasive, not a matter of episodic, occasional factors that might often, at least for short time periods be ignored.

With hindsight we can understand the role of some interactions of personalities and institutions via qualitative, econometric and non-parametric statistical methods. This is exceedingly valuable. It plays a role in firing and promoting some personalities, and in the typical changes that occur in official sector powers between the treasury and the central bank and the elected representatives after exchange rate crises, eg those of the UK after Black Wednesday in September 2002, Cobham (2002a, 2002b, 2006). Hindsight understanding enhances our predictive power in that there is a degree to which history repeats itself – but the degree is exceedingly limited when this involves fine details concerning individual differences. We are rather in a non-stationary, non-ergodic world.¹ It is implausible in such a world, wherein the individual differences are so critical, that we can succeed in enhancing our predictions to the extent of eliminating even half the current variance of medium term exchange rates about their predicted values.

The personality interactions and regime changes are by and large unpredictable. The field and laboratory evidence alike highlight the pivotal role of personality and group dynamics.

¹ The term was developed by the Moscow School of Probability in 1935. Ergodicity implies that samples drawn from past and current data furnish statistically reliable forecasts since economic time series are stationary. For critiques of EUT usage of the ergodicity assumption, see Davidson (1984, 1988, 1991, 1993, 1996).

Both highlight the inherent unpredictability of exchange rates – unpredictability not removable by discovering tomorrow how the economy really works. How then does a sensible reasonable official sector choose its exchange rate regime? The fundamental question is whether this unpredictability matters.

6 Macroeconomic Management Costs from the Unpredictability

6.1 Experimental Evidence

To ascertain whether exchange rate unpredictability matters, one form of evidence is an experiment. This can be used to estimate the relationship between unpredictability and macroeconomic management. If the relation is negative, this corroborates the hypothesis is damaging, and the more so the higher the absolute regression coefficient. The corroboration may however be by chance, an artifact of the data. It is thus informative to also test the null hypothesis that an predictable exchange rate is harmless for macroeconomic policy, against the alternative hypothesis that it is damaging, and ascertain the 1-tail significance level for the null, ie the likelihood that there is no damage yet the sample of data by being unrepresentative, gave this impression.

To this end, we conducted in the Bonn Experimental Laboratory an additional six experimental session with the same set-up as those described in Part 4 except that these six had only one currency, and thus only one central bank, and hence no exchange rate uncertainty. In the case of the currency union, there is no exchange rate, and thus one less goal for the central bank. In addition we assumed that in this case the governments differ in their objective from the central bank in being concerned only about over and under employment in their own country whiles the central bank cares about both. In other respects the two governments shared the objectives specified in Table 1.

In all sessions, with and without a currency union, firms could in making their decisions use a profit calculator that, in the two currency sessions, involved entering their exchange rate predictions. Analysis of firm use of this information reveals that firms has no capacity at all to predict the exchange rate, Kaiser and Kube (2005). We lack a like direct measure of whether the other private and official sector participants had like total inability to predict the exchange rate since these were not supplied with such input calculators. It is reasonable however to assume that these other participants also had difficulties in this regard, and that the more volatile the exchange rate, the less predictable it became for all concerned including the official sector.

In computing exchange rate volatilities in the experimental sessions, we wished to avoid asymmetries arising from choice of the exchange rate e from the perspective of one of the two lands, and relatedly from whether the exchange rate is rising or falling. For big exchange rate changes, such asymmetries are dramatic. We avoided these asymmetries by constructing the following symmetrised measure ε_e of exchange rate volatility.

$$\varepsilon_e = (\sum \{ \frac{e_t^A}{e_{t-1}^A} + \frac{e_{t-1}^A}{e_t^A} - 2 \}^2 + \sum \{ \frac{e_t^B}{e_{t-1}^B} + \frac{e_{t-1}^B}{e_t^B} - 2 \}^2) / 2,$$

where the superscripts A and B denote the pair of countries, and t denotes a period.

We calculated this for each of the 12 independent sessions (namely six with a currency union and six with two currencies and transparent central bank exchange rate targets), and 15 independent sessions, namely inclusive of the three additional sessions where the central bank exchange rate targets were non-transparent. We used a non-parametric correlation measure, the spearman rank correlation, to identify that there was a marked negative correlation between this volatility on the one hand, and central bank and government payoffs on the other.

We found a marked negative correlation with the central bank payoff, namely of -0.511 in the case of the 12 sessions, and of 0.422 in the case of the 15 sessions. With a one-tailed test, this is significant at the 2% level in the case of the 12 sessions, and at the 6% level in the case of the 15 sessions.

We found an almost as marked negative spearman rank correlation in the case of the government payoff, namely of -0.429 in the case of 12 sessions, and of -0.323 in the case of the 15 sessions. These were significant at respectively the 9% and 14% levels.

Thus for central banks, and a little less conclusively for governments, the laboratory data indicate that unpredictable exchange rates are costly for macromanagement.

7.2 Field Evidence

7.2.1 Taxpayer costs

Unanticipated depreciations cost taxpayers, via the central bank's balance sheet effect. This is one asset sheet where the ownership of the changed liability for the national taxpayer is known. The ownership of the windfall asset gain by contrast is to put it mildly, tricky to estimate. But even if all the transfers were within a country, the official sector's macroeconomic management is damaged by the effects these windfall gains and losses have on economic efficiency, and much of the gains go to foreigners. An example from the

early 1990s is the sterling crisis, whose cost to the British taxpayer Lawrence Summers, quoted in Dornbusch (1993), put at \$25 billion. An example from this millenium is the Australian Treasury loss of some \$3 billions by engaging in interest rate swaps in anticipation of the national currency appreciating markedly against the US dollar, when instead of several years it substantially depreciated, Letts et al (2002).

7.2.2 Market Interference and Non-Market Transfers

Macroeconomic management is damaged by financial chaos from spates of bankruptcies and renegeings on debt repayment schedules. Unanticipated depreciations can generate unmeetable debts. Much economic theorising ignores this under an assumption that firms and governments can and do hedge at a trivial cost. This assumption is counter to the stylised facts that are as follows. Hedging is more the exception than the rule. Hedging is available only for extended periods ahead only to large firms and then is so complex that firms choose inappropriate exotic derivatives that are too complicated even for the issuers to understand. This was one cause of Enron's demise after its unmeetable liabilities became too large to cover up. For smaller firms, hedging at any price is simply unavailable, McKinnon (2005). In short, for firms and governments borrowing and lending internationally, hedging has had in the past an exceedingly limited role in buffering firms from unanticipated exchange rate changes, and this can be anticipated to continue to be the case in the future. Big unanticipated exchange rate changes thus have and will continue to generate spates of bankruptcies and repudiated debts.

The threat each large scale financial unravelling after any exchange rate crisis is typically reduced by official intervention. This takes the form of arranging preferential treatment of some of those who might otherwise have become insolvent. Such official intervention can be vastly better than the alternative of a major international financial unravelling. But through its interference with efficient and fair markets, it is damaging to macroeconomic management. Further the preferential treatment can be so preferential to some countries over others that for some countries the damage to macroeconomic management is arguably worse than if no official sectors had stood in the way of a financial unravelling.

An example is when in the early 1980s, the US dollar roughly doubled in value, and numerous firms and governments located in the mirroring depreciating countries had failed to hedge their US dollar borrowings. These suddenly were doubled in local currency terms. It suddenly twice as much had to be repaid. For many developing countries honouring promptly debts that were suddenly over twice their original magnitude was infeasible. In

part to protect their multinational financial intermediaries from the dangerous unravelling repercussions, the US and EU official sectors were parties in many of these negotiations. These negotiations used non-market preferential procedures to reduce the bad debt problem of favoured multinational financial intermediaries at the expense of others, Cleary et al (1998), Stiglitz (2002) and Barro and Lee forthcoming.

A second example of an unravelling threat and preferential treatment to very wealthy persons is when Long Term Capital Management failed to forecast the Ruble's exchange rate depreciation in the late 1990s. Alan Greenspan, as chair of the US Federal Reserve System, felt he had to consider whether this might not lead into a 1929 style depression. Greenspan accordingly visited that hedge fund's underwriters and proposed that they take actions that would limit this damage, Davidson (2005).

8 Reasons for Neglecting the Damage

The sums involved in unplanned exchange rate changes dwarf all other conceivable means for the official sector to alter a nation's wealth. The seriousness of the issues surrounding unpredicted exchange rates are almost impossible to overstate. They can topple the entire international financial system and plunge not merely the third world into poverty, but also the first. These major, unpredicted, unwanted and disappointing exchange rate changes have bedevilled macroeconomic management in the 37 years that have elapsed since the breakdown of the Bretton Woods Agreement. Yet, to the authors' knowledge, their costs to macroeconomic management have had little in the way of econometric investigation.

8.1 Data Scarcity

An obstacle is obtaining data on the inter-country distribution of the ownership of those assets that undergo unpredicted revaluations – and thus undergo unpredicted changes in the inter-country distribution of credits and debits after each exchange rate change. Some developing countries continue to regulate their exchange rate market, have retained capital controls, Vernengo and Rochon (2000), von Hagen and Zhou forthcoming. The dropping of capital controls and the progressive deregulation of capital markets followed the demise of the Bretton Woods Agreement and meant that former ways of estimating these magnitudes were no longer available for most countries by the early 1980s.

8.2 The Borderless Capital Perspective

Some of the data loss however was voluntary – deliberate. Countries like Australia quit collecting data even on the domestic / foreign ownership composition of financial and

physical assets. This was because of the mentality that information about the residence status and nationality of those issuing debt and credit was irrelevant, that recording such information was market interference, Pope (1986).

A difficulty with the new mentality is that macroeconomic management concerns prices and quantities *within* national borders, assets *owned by nationals* and inflows and outflows of capital to that *particular nation*. These in turn are intimately bound up with the drastic revaluations of credits and debits in the national currency after each exchange rate change – about which limited data are available, but not with the critical delineation of national ownership of the assets and liabilities.

8.3 Tractability

It is a daunting task to do either theoretical or empirical work that takes seriously the changes in wealth, purchasing power, consumption and investment incentives, inflationary and employment effects that take place after each exchange rate changes. It is especially daunting when the world contains so many different currencies and associated national spending groups. The reality has been primarily international capital flows as if in a closed economy in this respect – or at most as if there are two countries in the world – but more frequently as if wealth does not exist, as if there were no intercountry, no interpersonal and no inter-firm wealth transfers after each exchange rate change. When the wealth effects are unmodelled, the damage of unpredictable exchange rates from its impact get ignored.

9 EUT

The breakdown of Bretton Woods at the beginning of the 1970s and the onset of damage from unpredictable exchange rates coincided with a major change in financial modelling. Previously many decision models considered variance and thus unpredictability – eg the Sharpe-Lintner capital asset pricing model. Concomitantly scientists examined the means taken by agents to reduce the costs of this variance – eg the diversification models of Tobin (1958) and Markowitz (1959).

But then came the demonstrations of Borch (1969) and Feldstein (1969) that such elaborations on the pre-world war 2 mean variance models violate EUT.² Concern about variance and its costs vanished from mainstream theoretically respected work. In

² It might seem from Borch and Feldstein that there can be an accidental coincidence, eg via a quadratic utility function or a normal distribution of outcomes. But, apart from the reality that the distribution of financial asset outcomes are typically fat-tailed and not normally distributed, there is the problem that all these coincidences violate dominance, and thus EUT when, as in all finance applications, the outcomes space is specified in monetary amounts, Scheeweiß (1968a, 1969b, 1973a, 1973b). In short, there is not even the scope for accidental coincidences.

econometrics, Tobin lost an anticipated multi-million dollar econometrics grant because his modelling considered variance.

In finance, in contrast to economics, after 1969, there was scarcely a drop of interest in variance as an independent goal. To the contrary, new extensions of mean-variance models have been developed and used, eg Fama and French (1996, 2004). This was partly because the importance of variance was impossible to overlook in serious descriptive and prescriptive modelling of asset portfolios by those seeking consultancies, and partly because it was fairly soon afterwards discovered that under an assumption of complete perfect state contingent asset markets, there can be a coincidence of mean-variance style models and EUT.

This coincidence is an important intellectual discovery. This intellectual discovery, along with other evidence that their models were seeking to approximate EUT, preceded the award of Nobel prizes to those who in the 1950s promoted the traditional modelling of concerns about variance, Pope (1996/7). But since the perfect complete state contingent market does not exist, the coincidence does not exist. Scientists seeking to consistently adhere to EUT avoid mean variance analysis and are thereby deflected from assessing the damage of unpredictability in analysing exchange rate regime choice.

Let us look in more detail at what EUT is, and at what it excludes.

9.1 The Impractical Impossible Maximising Assumption

EUT assumes that decisions are made on a maximising basis. But field evidence demonstrates that central bankers employ non-maximising procedures, eg Cobham (2006), and central bankers advance sound argument for this being appropriate, eg Papademos (2006). The maximising assumption has also been found false for participants acting as central bankers in a laboratory setting, as reported in Part 5 above.

It might be thought that economists who advise governments on choice of exchange rate regime are superior to central bankers and the experimental participants in our laboratory design, none of whom had yet obtained their doctorates, superior in the sense of being capable of applying EUT in their analysis of regime choice. But this is false. Maximising requires, amongst other preconditions an infeasible amount of computation, Radner (1968) and Simon (1991, 1996), and hence also is infeasible for economists. When maxima are infeasible to calculate, it would also be difficult for economists to advance any empirical means of ascertaining whether actual choices can in any sense be said to approximate what EUT assumes are maximising ones.

Savage (1954, 1972) had addressed the maximising problem, and owned that EUT is impractical even for planning a picnic. Savage sought to solve this practicality issue via a small worlds assumption. But identifying how it could render EUT practical, he found too difficult a task, and left it to future researchers. To the authors' knowledge, no progress has been made since on rendering small worlds, and thus EUT, practical.

9.2 The Riskless Utility Mapping

Even were it feasible to solve the difficulties with small worlds and thus apply EUT, it would be normatively inappropriate. This is because that theory's axioms restrict the outcomes flow to which utilities attach to: (i) the segment after all risk is passed, and (ii) being evaluated "as if certain", Friedman and Savage (1948), Samuelson (1952), Pope (2006). This pair of constraints excludes the evaluation stage in which heuristics have to be used to overcome the practical matter identified by Savage. It also excludes the emotional and financial experiences undergone after making a choice and before learning the outcome, including loan limits, and the legacies of these experiences, eg repayment of risk premia augmented interest charged, and inefficient planning.

Under EUT, risk does not affect any experiences in real time. It enters only atemporally, in the aggregation of the mutually exclusive outcomes in the case of these being expressed in a monetary scale, with the functional form of the utility mapping being non-linear. Actually risk does not even enter atemporally in the aggregation process in the standard finance assumption of linear utility! The same comments hold for all standard rank dependent extensions of EUT.

9.3 The Omitted Risk Planning Inefficiencies

Let us illustrate the real time experiences that EUT omits by excluding from its utility mapping the earlier segments of the outcomes flow. Let us illustrate with the planning inefficiency problem that arises on those occasions when in exchange rate crises, central banks cost their taxpayers billions of dollars through unanticipated depreciations. The central bank causes the loss by selling foreign assets in an attempt to avert a depreciation.

If the central bank knew (100% certainty) that there would be a depreciation, it would not do this.³ What causes these massive losses of taxpayers' funds is that sometimes the central bank's dare works and the country rides out the depreciation threat, ie it does not depreciate at all. With no uncertainty in the future – ie when (if the uncertainties can be expressed as a probability distribution) the variance is zero – a central bank can plan efficiently. A central

³ We ignore here the leaked information of central bank staff in some countries speculating against their own currency and making large fortunes from these allegedly unanticipated depreciations.

bank would never sell its foreign assets if in the immediate future, its currency is guaranteed to depreciate. Variance is a curse to efficient central bank stewardship of the taxpayers' foreign exchange assets.

This damage to efficient planning from variance is the mirror image of variance being a curse to lenders in the form of their being only contingently repaid, and as a consequence of higher variance demanding recompensing higher risk premia, or lending less, or both. No lender can plan his intertemporal allocations efficiently when uncertain about the future. The efficient truth telling market thus imposes risk premia and loan limits, Pope (2005). This contributes to the equity premium "puzzle", and has a rough approximation in mean-variance modelling and extensions thereof as a decision procedure, Pope (1995).

9.4 Efforts to Enlarge EUT

There have been efforts to expand EUT to consider the planning inefficiencies caused by unpredictable exchange rates – and the associated other financial and emotional ramifications of this unpredictability and other sources of unpredictability. The implausible decisions made under EUT as a result of these planning inefficiencies was made salient in Wold (1952a). The first idea was that the planning problem could be side-stepped by imposing on the decision maker a single choice, Samuelson (1952b), Savage (1952a). As Wold (1952b) remarked, this made EUT impractical, and Savage (1952b) responded that he hoped to find a way to render it more practical. Savage (1954, 1972) reported that restricting EUT to a single decision meant that new born babes made at birth their once-for-life choice and thereafter no more choices, merely implementing their strategy, but that in trying to make the procedure more practical, he had encountered only impasses.

By the early 1950s however, people were discovering other planning and related problems for EUT. These other problems could not be overcome by restricting choices to a single once in a lifetime choice of new born babes. Efforts to address these other problems include techniques like elaborating outcomes or more fully describing the decision situation or converting the outcome space from money amounts into consumption amounts. But these techniques destroy the theory's axiomatic base, Pope (2000, 2005). A few models obtain decisions that coincide with those from a decision theory include a restricted set of these effects from having dated non-degenerate probability onset and expiry dates in an extended EUT, eg Kreps and Porteus (1978, 1979) and Klibanoff and Osdenoren (2006). But the coincidences are limited and such models to date have proven to be too complex for application in exchange rate regime analyses, Pope Leitner and Leopold (2006).

When EUT is confined to the outcome flow segment *after* all risk is passed, its axioms are violated if in an application to regime choice, reducing exchange rate variance is a goal taken into account by the official sector. When EUT's axioms require every outcome to be given the same utility number as when it is certain, there is no scope for the variance of the outcomes to be an independent goal that enters the mapping from outcomes into utilities and thus into the valuation of an act such as an exchange rate regime, and thus choice of exchange rate regime.

This "as if certain" EUT mapping restriction underlies the findings of the incompatibility of EUT with mean variance decision models. In these mean-variance models, in addition to an expectation term, choosers put an independent value on the dispersion of outcomes, something that is incompatible with EUT, as proven by Schneeweiß (1968a, 1968b, 1973a and 1973b), Feldstein (1969) and Borch (1969). In other words, an EUT obeying official sector cannot, as the producer of exchange rate regime, seek to offer a product to stakeholders that includes as a separate independent consideration reduction of exchange rate variance.

10 Stages in Knowledge Ahead

Variance is an experience in the period before all risk is resolved, an experience during what is in Pope (1983, 1995), termed the *pre-outcome period*. Caring about variance of the outcomes is a contradiction in terms if as under EUT there is only utility attached to the outcome segment after all risk is resolved. To care about variance, it is necessary to include the *pre-outcome period*. This is the period when there is variance – when over the mutually exclusive outcomes, the distribution is *not yet degenerate* because the final outcome segment is yet to be learned. Once the outcome is learned, we have reached what may be termed the *post-outcome period*, when all risk is passed and thus when variance is zero. Consideration of variance is thus exclusively a consideration of something that exists in the *pre-outcome period*, a period that EUT excludes from its utility mapping.

Von Neumann and Morgenstern recognised that people care about something that they called by many names including the utility of gambling, and that in Pope (2001) is given the name of secondary satisfactions so as to avoid the misleadingly denigratory and narrow connotations, and to avoid the misunderstandings that have arisen in connection with other terminologies. For lists of the other names that von Neumann and Morgenstern and their predecessors and successors have used for this phenomenon, see Pope (1996/7 and 2001).

Von Neumann and Morgenstern discerned that the phenomenon of the utility of gambling involves people getting positive and negative satisfactions from the distribution of outcomes – from whether there is more than one possible outcome. They recognised that EUT was too narrow in limiting people to getting satisfactions (utility) from each outcome independently of risk, as if certain – and thus independently of there being other possible outcomes. They discerned that positive and negative satisfactions from dispersion (and thus of variance being non-zero) implies an interdependence between the mutually exclusive outcomes (in the language of quantum physics, a complementarity). They described such interdependence as a contradiction, since in their axiomatisation they explicitly limited the utilities to pertain in the period after all risk is passed (1947, 1953, 1972 and 1983, p19).

Indeed utility from the interdependence is infeasible if there only were the era after all risk is passed. If there is only a riskless era, the probability distribution is degenerate. Variance is zero and was from ever in the relevant past till to ever in the relevant futures. In turn this means that there can be no planning inefficiencies and other legacies from a previous period of risk, uncertainty.

Von Neumann and Morgenstern failed to find the higher level, required to solve the contradiction, and left the task of finding it to future researchers (1947, 1953, 1972 and 1983, pp628-32). That higher level involves replacing EUT, which as they themselves remarked, is static as regards knowledge ahead, by SKAT, the Stages of Knowledge Ahead Theory, Pope (1985b), and Pope, Leitner and Leopold (2006). SKAT recognises that a precondition for an alternative to be risky is that there is at least one stage prior to the *post-outcome period* when all risk is passed and certainty reigns.

SKAT recognises that immediately before the *post-outcome period*, there is the *pre-outcome period*, namely the period that elapses after a risky alternative has been chosen. During the *pre-outcome period* the variance is non-zero, experienced and affects satisfactions, welfare. This is because during the *pre-outcome period* more than one of the mutually exclusive outcomes is still possible. It is only after all risk is passed that variance is zero – ie that the *previously non-degenerate* probability distribution has become *degenerate*. But because there is the prior *pre-outcome period* of risk, of uncertainty, under SKAT, there can also be in the *post-outcome period* after all risk is passed, legacies (blessings, damage) from that *previous uncertainty*.

Under SKAT, moreover, a yet earlier stage than the *pre-outcome period* can be consistently modelled, namely the stage when alternatives are evaluated. This opens the way for

economists to consistently take into account how central bankers and others actually evaluate and choose. It can avoid the implausible impossible EUT assumption that this stage is costless and timeless as regards utility, and thus is a segment that can be ignored in the utility mapping

In summary, SKAT, the Stages of Knowledge Ahead Theory, can consistently incorporate concern that choice of an exchange rate regime may yield a wide, even very wide, scatter of outcomes about the mean. Under SKAT we can take this unpredictability into account, and the real time planning inefficiencies of uncertainty generated by unpredictability, and conclude that this consideration points to abandoning floats, furnishes another reason for exchange rate regimes being advocated to an extent for other reasons, namely dollarisation, eg Alesina and Barro (2001), currency unions, eg Courchene (1999a, 1999b) and Courchene and Harris (1999), Rose (2000, 2004), Cobham (2006) and a single world money, eg Mundell (1961, 2003).

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