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ORIGINAL PAPER

# Exchange rate determination: a theory of the decisive role of central bank cooperation and conflict

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**Abstract** Economists' faith that variable exchange rates benevolently equilibrate has been *empirically* disconfirmed. That faith is here tackled at its *theoretical* core with an exchange rate model that although ultra abstract, includes the *undeniable fundamentals of market power and differential goals of central bankers and large-scale private players*. It permits a game theoretic analysis under the assumption that all agents maximize their payoffs. The paper then relaxes the assumption of maximising agents, allowing for a more complex and thus realistic second version of the model that is interpretable within SKAT, the Stages of Knowledge Ahead Theory of risk and

The text is written by Robin Pope, with valued improvements on successive drafts from comments of Johannes Kaiser and Reinhard Selten. The participants' instructions here reported are based on those written by Sebastian Kube and translated into English by Reinhard Selten, with minor improvements on these from Robin Pope. The calculations requested by Robin Pope were kindly furnished by Johannes Kaiser. The particular model within the central bank conflict co-operation theory of exchange rate determination is that of Robin Pope and Reinhard Selten, with valued input from Juergen von Hagen on allowing for the distinct input of the government sector. The operationalisation of the model into a computer-programmed set-up is that of Sebastian Kube and Johannes Kaiser. We thank for comments Paul Welfens; for background information Richard Cooper and Herbert Grubel; for editorial assistance Pulikesh Naidu; for research assistance Corinna Wassermann, Daniel Lederer, Andreas Orland, and Laura Frank; and for funding the Center for European Integration Studies and the German National Science Foundation. The paper does not reflect the opinion of the Deutsche Bundesbank.

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uncertainty. In an experimental setting, this second version of the model points to: a) the inability of agents in central banks, governments and the private real and financial sectors to operate in maximising ways; b) destructive central bank conflict; and c) the widely discrepant outcomes arising from the dynamics of individual personality differences. The paper's theoretical and empirical findings thus both point to the merits of a single world currency.

**Keywords** Central bank · Cooperation · Conflict · Exchange rate · Experiment · Market power

**JEL** F310 · F330 · B400 · B590 · C790 · C900 · C910 · C920

In understanding the relative merits of multiple currencies as against a single world currency, this paper seeks to shed fresh light via an analysis that allows for seven complexity impacts on the exchange rate that are underplayed (where not entirely absent) from current analyses, namely the:

1) dominating market power of governments and central banks;
2) different sorts of private sector agents and their different goals;
3) disparate degrees of market power of different sorts of private agents;
4) matter that nearly all shocks to the exchange rate are generated by human decisions, not random acts of nature;
5) heuristics that, in a complex economy, agents use;
6) heterogeneity of these heuristics amongst public and private sector agents;
7) distinct personalities of those holding key degrees of market power, and how the group dynamics arising from personal friendships and enmities alters these individuals' choices over time.

This paper analyses two versions of a model within the central bank conflict-cooperation theory of exchange rate determination. The first version combines fundamentals 1 to 3 with the conventional finance assumption that all agents maximise their utilities. The maximisation cannot be under a so-called rational expectations equilibrium since rational expectations ignores market power and the market power of central banks and key private players are the hallmark of exchange rate markets. The maximisation might conceivably be under a new game theoretic notion of incomplete equilibrium, but maximization per se is demonstrated to be implausible.

This first version is nested within a second more general version as we relax the implausible assumption that all agents wish to, and have the ability to, maximise their utility within any notion (benchmark) of equilibrium being played by themselves and all other players. We allow for the possibility that instead agents seek to attain their goals via personal decisonmaking heuristics that generate shocks for themselves and the other agents. The relaxation of the maximising assumption, allowing for effects (4) to (7), is by means of an experimental investigation.

Parts 1 and 2 survey the case for multiple currencies, the methodological dogmas that prevent many economists from noticing the damage from multiple currencies, and why this paper abandons those methodological dogmas. Part 3 lists defects in current exchange rate modelling, the paper's remedies, and the advantages of

presenting models in the form of instructions to participants in an experiment. Part 4 elucidates some of the features of the paper's model within the central bank conflict-cooperation theory of exchange rate determination in the normal impersonal way. Part 5 explains the advantages of presenting a complex model to readers in the form of instructions to participants. Part 6 specifies the model's details in this instructions form. Part 7 uses the first version of the model to uncover the misleading and somewhat inconsistent equilibrium modelling of shocks in conventional exchange rate models. Parts 8 and 9 concern the refutation of exchange rate equilibrium as a useful notion and use laboratory experimental data to delineate why equilibria are unspecified once shocks from humans enter the picture. The laboratory results demonstrate the non-equilibrating role of central bank conflict and cooperation in determining the exchange rate, and how inadequate central bank cooperation enables firms to also have some influence on exchange rates. Part 10 indicates the scope for investigating other issues using this model, and how observed behaviour can be interpreted in the light of SKAT, the Stages of Knowledge Ahead Theory. Part 11 indicates extensions and alternative models that might be developed employing the central bank conflict-cooperation theory of exchange rate determination here presented

## 1 The case for multiple currencies

Having multiple currencies is a choice, not a necessity. Many have contributed to this choice. Their voices have been powerful enough to preclude the reinstitution of some form of a single world currency as substantially pertained in the heyday of the gold standard.

These voices assume benefits from varying exchange rates, many agitating for even more exchange rate changes. There has been over a decade of calls for China to appreciate. The calls have come from academic economists such as Cline (2005), Simmons (2006), Zemin (2007), Davidson (2009) and Cooper (2011). The call has also come from politicians, from the US Senate, the United Nations Conference on Trade and Development (2010), Soros (2010a, b), and at the February 2011 G20 meeting, from Geithner, US Secretary of the Treasury and also from Bernanke, Chair of the US Federal Reserve Board. In a similar vein the EU has accused China of engaging in a "currency war". See eg Bernanke (2010) and Asymptotix (2010)

Those opposing this pressure for a Yuan appreciation are a minority–China's government and central bank, and academic economists such as Mundell (2003, 2005), McKinnon (2006a, b, c, 2007a, b, 2010), Wang et al. (2007). It has likewise been a minority who object to US President Reagan and the west pressuring Japan into its drastic 2,000% appreciation of the yen in the mid 1980s and Japan's subsequent abrupt collapse in trade, and the entire economy, Seeman (1984), Leamer (2011). Again it is a minority who declare that the EURO has aided continental Europe, and could aid the UK, e.g. Grubel (1999) and Kammerer (2005). The majority perceive that currency union as a throttle on macro-economic management and recovery from crises, e.g. Roubini (2010). It is likewise a minority, even a dwindling minority, who contend that Canada would be better served by adopting the US dollar (if it cannot negotiate a seat on the US Federal Reserve Board), and that the North American Free Trade Area would be better served by a common currency, e.g. Courchene (1999), Courchene and Harris (1999), Grubel (1999).

The majority case for variable exchange rates has several prongs. Amongst economists, the principal prong is a belief in beneficially equilibrating exchange rate changes. This prong has two variants. One variant rests on faith that *policy engineered* exchange rate changes can be benevolently equilibrating, e.g. Reinhart and Rogoff (2004, p10). But a review of policy-engineered exchange rate changes advocated by economists reveals decisively that economists cannot discern equilibrium, and instead unwittingly in a systematically biased beggar-thy-neighbour manner advocate exchange rate changes, Pope (2009).

Alternatively, economists who uphold the faith that exchange rate changes are benevolently equilibrating, argue that market forces (not wicked government interventions) ensure that exchange rates benevolently equilibrate supply and demand fundamentals. The market force argument is defective on several logical grounds, Levich (1989). Not surprisingly therefore, within the three-year horizon pertinent for macroeconomic management, such fundamentals have proved undiscoverable. Models based on these supply–demand factors fail to predict out of sample better than a random walk, Meese and Rogoff (1983), Pagan (1993, 2005), Engel et al. (2007), Pope and Selten (2011a). In short both prongs of the case that exchange rate changes are equilibrating are disconfirmed.

Another case for variable exchange rates is that it is nationalistically gratifying for a country to have its own currency. This is implicit in some economists' observations that they would not want a single world money since a world central bank's monetary policy might be unsatisfactory. There are two ways for this argument to make sense, both nationalistic. One is that these economists believe nationalistically that their own national central bank would be superior. The other is that these economists dislike supranational authorities, so denigrate them, even if they cannot construe a case for why the supranational central bank would be likely to be inferior to their own national central bank. Both of these nationalistic interpretations are explicit in the popular press in numerous countries.

Such nationalism fosters inter-nation trade wars and physical wars. Precluding a third Franco-German war was a major factor in the Franco-German collaboration leading to Euro. This paper repudiates a pure nationalistic justification of multiple currencies.

Apart from nationalism the other case for multiple currencies is that the institution of a single world currency would take effort, Cooper (2009). The effort of instituting a single world currency needs to be weighed against the damage from the current situation of drastic unpredicted exchange rate changes. But according to most supporters of multiple currencies, such damage is minimal, e.g. Rogoff (2001).

The evidence adduced that the damage is minimal however rests on false, misleading and unbalanced arguments that fail to notice and grapple with the ugly side of exchange rate liquidity shocks. The arguments fail to mention that exchange rate liquidity shocks inflict on developed countries billion dollar losses to their central banks, government treasuries, send into unemployment workers and send into receivership many of their most valued multinationals, Pope and Selten (2011a, b, c). The arguments fail to mention the ever more drastic damage suffered in the developing world where exchange rate liquidity shocks eviscerate governments and entire economies, Leamer (2011).

The failure of economists advocating variable exchange rate changes to notice such economic wounds is analogous to the behaviour of the priest and the levite in the

parable of the good Samaritan. The priest and the levite cross the road to avoid sullying the upcoming Sabbath purity by noticing and tending to the wounded man attacked—in the parable, by robbers—in the economic realm, by unpredicted exchange rate changes.

This paper deems that economists have scientific and ethical responsibilities to mention the economic wounds and deaths arising from these exchange rate changes. It considers that economists have like responsibilities to go beyond blind faith that exchange rate changes provide benevolent equilibration. It judges that 40 years of empirical investigation failing to discover a single case of equilibration within a pertinent time interval is a failure of the equilibrating exchange rate theory. It judges that this discovery failure warrants the conclusion that exchange rates do not in any meaningful or discoverable way benevolently equilibrate anything within a policy-pertinent time frame for governments, businesses or households. It deems that it is incumbent on economists to investigate whether macroeconomic management and general economic welfare would be superior under a single world currency.

## 2 Methodological purity dogmas

Multiple factors underlie the refusal of those economists who endorse the choice of variable exchange rates to mention the decisively disconfirming empirical evidence for exchange rates being equilibrating or harmless. One factor is a disconnect from the real world, a retreat of economics into six methodological purity dogmas that they hold as incontrovertible a priori truths. Table 1 illustrates for the case of exchange rate models.

This paper repudiates these five dogmas on the basis of an alternative methodology, that of the physical sciences, wherein empirical evidence matters, and also on the basis that ethics and normative values are an inextricable part of any scientific investigation, Putnam (2002).

The maximisation dogma is repudiated on the basis that empirically it requires more brain power and information than economic agents possess, something admitted

**Table 1** Five a priori truths – economics methodological purity dogmas

| | |
|---|---|
| 1 Maximisation | agents maximise |
| 2 Simplicity and elegance | esteemed scientific economic models and experimental set-ups concerning the exchange rate are simple, elegant |
| 3 Traditionalism | worthwhile scientific economic models and experimental set-ups concerning the exchange rate preserve tradition–extend mainstream models in which exchange rates equilibrate and the Mundellian notion of optimal currency areas is pertinent |
| 4 Universalism | worthwhile scientific economic models and experimental set-ups concerning the exchange rate assume that the core neoclassical model holds universally |
| 5 Context free modelling | objective scientific models and experimental set-ups avoid non-economic contextual variables |

in Savage (1954), but then ignored by him, and subsequently by all economists who converted to expected utility theory.

The elegance/simplicity dogma is repudiated on the grounds enunciated by Einstein and pressed in economics in Manne (1952) and Allais (1979). The grounds are that science is about explaining phenomena, not conforming to an aesthetic standard, and that a scientific theory should be simple, but not simpler than required to explain the phenomena. All those exchange rate models so simple and elegant as to be algebraically tractable, econometrically estimable or quick to replicate in an experimental laboratory routinely fail the key test, of having explanatory power in the pertinent policy time span.

The traditionalism dogma is that in Mundellian fashion, exchange rate changes benevolently equilibrate particular classes of shocks caused by changes in supply–demand factors. The traditionalism dogma is repudiated on the grounds of the failure to discover any robust supply–demand factors whatsoever that cause changes in the exchange rate within a policy pertinent time frame. A radically different approach, not yet one more variation on tradition, is indicated. Tradition has had enough time to discover these supply–demand factors if they exist in the four decades that have elapsed following the demise of Bretton Woods. Yet none of the successive "new generation" exchange rate enhancements of traditional mainstream economics models have discovered anything robust–none have managed out of sample to more than marginally out-perform a random walk within the pertinent time span.

The universality dogma is repudiated on the grounds that different economic phenomena involve different causal phenomena since different institutional and legal phenomena are pertinent. In neither case have neoclassical models in which quantities supplied and price are the fundamental building blocks had predictive success. A relevant economic model of the tripling of the oil price in 1973 includes OPEC decisions as a causal factor, but not decisions of central bankers. By contrast, after 1980, no relevant economic model of exchange rate changes can omit decisions of central bankers.

The context-free dogma is repudiated on eight grounds. First, empirically agents supply themselves the context for abstract choices in an experiment, namely the context closest to it, which for risky choices is often a frivolous lottery context, Conlisk (1993). Second, empirically models need to be ultra brief if abstract, since otherwise readers realise that they cannot follow them enough to operate in an experiment.

Third, while readers think that they understand and endorse a feature in an abstract model, making the context concrete often reveals that they misunderstood the feature, and would not endorse it. For instance economists and decision scientists almost universally endorse a feature of expected utility theory and its standard generalisations, namely the preference for first order stochastically dominating options. But when presented with a concrete decision situation that is adequate in context and framing, they repudiate this feature not merely in descriptive models but also in normative models, Pope (2001).

Fourth, empirically people do make different decisions in different contexts. They tend to take more risks in the context of choosing in their private capacity, to be more prudent when choosing in their capacity of being a government official, or advising on government policy, Krzysztofowicz (1983). Fifth, normatively, context ought to influence decisions, McKie and Richardson (2003), Richardson and McKie (2007a). Sixth, empirically, how others frame the context alters choices, Tversky and Kahneman (1981), Arrow (1982).

Seventh, empirically in complex situations, choosers must themselves frame to formulate heuristics and reach a decision. In this regard, in the complexity of determining exchange rates, heuristics concerning prominent numbers have been influential over millennia. Such prominent numbers heuristics are evident from field studies (the use of chartism and technical analysis), and also in laboratory experiments, Pope et al. (2011a), (b).

Eighth, some contextual framing is uneliminable. In turn this makes it incumbent on the scientist to pay close attention to his own framing, not to imagine that he employs no framing. The scientist ought to select ethically appropriate framing of the theory to steer scientists, policy makers and the general public toward better models and policy advice. Gigerenzer and Gray (2011) offer framing improvements in medical models. There is a like ethical need for framing improvements in how academic economists present theories of the determinants of the exchange rate.

Can we stop being the priests and Levites of the good Samaritan parable, walking by on the other side as workers, firms, governments and central banks lie wounded by exchange rate changes? Such priests and Levites have to walk by since admitting and seeking to mend such wounds would introduce non-universalities, complexities and context and framing specific considerations that pollute the methodological platonic purity imposed by Table 1.[1]

Once we abandon the five purity dogmas of Table 1, we can grapple with the distinctive institutional and personal decision making realities of exchange rate determination. We can stop pretending to be in some imagined universal (typically Walrasian) market, and grapple with real world complexities, for what they are, real world phenomena, not ignore them as pollutants of our methodological purity. We can investigate whether or not with a single world currency, overall economic wounds would be less, since there is better macroeconomic management.

## 3 Defects in current modelling and analyses and their remedies

### 3.1 The defects–conflicts with the stylised facts

#### *3.1.1 Defect 1*

Politicians, government treasuries, and central banks have numerous goals, yet exchange rate models rarely embrace more than two–one inflation and one employment target. Likewise the goals are distinct for different sorts of private agents, such as firms and wage bargainers. Yet exchange rate models rarely model this *goal heterogeneity*–something not to be confused with *heterogeneity of information* available to agents with *identical* goals.

#### *3.1.2 Defect 2*

Exchange rate powers are split differently in different countries between the government, the treasury and the central bank. For simplicity and brevity, in this paper, we assume exchange rate powers lie exclusively with a country's

[1] Richardson (1993, 2000, 2002), Richardson and McKie (2007b), Richardson et al. (2010).

central bank. Any pair of fully cooperating central banks have unlimited power to set their bilateral exchange rate. This far exceeds the market power that arises and receives economic and legal attention in stock and commodities markets.[2] Yet in exchange rate modelling this utterly decisive market power of fully cooperating central banks has been underplayed, *indeed often totally overlooked*, in exchange rate modelling.[3]

### *3.1.3 Defect 3*

Central banks only episodically fully cooperate. Whenever there is some degree of non-cooperation or conflict between central banks, an important degree of market power is exercised by third parties including major private speculators (such as Soros and, in its heyday, Long Term Capital Management Fund), and wage bargainers. But such market power is generally ignored.[4] There is widespread usage of *so-called* rational expectations that are in fact irrational, as they ignore such market power entirely. Since fully cooperating central banks are exceedingly rare, the key players are more than the central banks. In the interval of conflict/incomplete cooperation between central banks, the wage bargainers and big funds have significant amounts of market power, Soros (2003). Had Long Term Capital Management better appreciated this and not relied on its zero market power Black Scholes formulae, it might not have needed to face the dramas it actually endured.[5]

### *3.1.4 Defect 4*

Shocks are modelled as exogenous, either as a one-off shock after which there will never be another shock and all know this, e.g. as in Mundell (1961), or else as if randomly generated by nature, not human choice. In the exceptional occasions where the shocks are modelled as coming from people, e.g. as having the shock, changes in people's work-leisure indifference curves, the nature of the shocks *prima facie* conflict with the model's rational maximisers assumption. Now shocks from nature happen, such as those underlying the worldwide grain shortage of 1969–70, the Italian drought escalating the prices of fresh produce at the time of the introduction of EURO notes and coins, and the Queensland floods raising the price of coking coal in 2011.

But major shocks to exchange rates never come directly from nature. All come from human decisions. This is true even of the March 2011 rise and reversal in the

[2] We are indebted to Paul Welfens for drawing our attention to the asymmetric attention of economists and lawyers to modelling market power in stocks and commodities price setting where individuals whilst nearly all ignore central bank market power despite central bank power being so much more decisive in setting exchange rates than is the market power of those influencing prices in stock markets and commodities exchanges.

[3] An important exception is Hausken and Pluemper (2002).

[4] 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 the model of Hausken and Pluemper (2002).

[5] Observations of Robert Merton on the Reasons for Long Term Capital Management's problems, made at the beginning of his presentation to the American Economic Association Meetings, New Orleans, 2001 dissenting with the view that this hedge fund's demise had "nothing to do with science".

yen following the March earthquake. The sudden appreciation of the yen on 14–16 March arose from speculators' decisions in anticipation of yen repatriations to pay earthquake insurance claims. The equally abrupt reversal of this appreciation 17–19 March arose from a G7 decision to jointly intervene to undo that rise, Kihara and Kajimoto (2011).

The breakdown of Bretton Woods was not even indirectly related in any way to a natural event–an out-of-space meteor, damaged grain crops, or a tsunami. Rather, the breakdown may be attributed to the way the US funded its Vietnam War, the beliefs of key adviser Milton Friedman and US pride barring a depreciation against gold, Pope et al. (2008).

Likewise subsequent exchange rate crises of the developed world, such as the doubling of the US exchange rate against key European currencies between 1982 and 1985, was the product of human decisions–those of US President Ronald Reagan to cut taxes and escalate military spending, of US Federal Reserve Board chair Paul Volcker to rein in the US money stock, and of US Secretary of the Treasury Donald Regan to endorse the strong US dollar and bar foreign exchange interventions to sterilise these extreme fiscal and monetary policy moves.

Again the halving of that exchange rate in the next 2 years was not that a hurricane had blasted the US economy into misery. It was rather British prime minister Maggie Thatcher's influence on her friend Ronnie Reagan to reverse this doubling. This influence of friendship, coupled with support from all the other key currencies, resulting in the Plaza Accord among the big five of 1985 and the Louvre Accord of 1987. On this trio of crises and their entirely human decision origins, see e.g. Paul Volcker's account in Mehrling (2001), and Pope and Selten (2011a).

The exchange rate crises of the early 1990s for the developed world were likewise also entirely of human making. The undesired sterling depreciation and exit of the UK from the process leading into the EURO occurred when the German central bank refused to co-operate with the Bank of England. However a year later when the French Franc faced a speculative attack, the cooperation of the German central bank resulted in sufficiently minor depreciation of the French Franc for France to remain in the process leading to the European currency union. On these 1990s crises, see e.g. Eichengreen and Wyplosz (1993).

To some extent the former and current US Federal Board members may have contributed to the global financial crisis of this millennium,[6] by not checking on banking fraud and ignoring how "sweeping" effectively eliminated bank reserve requirements. (Sweeping with super computers allowed banks to so swiftly shift funds as to circumvent any impact of reserve requirements.) The behaviour of Federal Board members was likely assisted by the empathy for the financial sector (with whose members they must socialise in their course of business). The financial sector makes capital losses from interest rate rises. As documented in Kriesler and Nevile (2003), a central banker can sometimes acknowledge publicly the undue pressure exerted by this sector as did one of the governors of Australia's central bank, Bernie

[6] See Telser (2007a and b) on the Federal Reserve Board's decision to ignore "sweeping" that effectively eliminated some bank reserve requirements that reduced bank profits but also beneficially reduced excessive competition among banks, excessive in that it leads to unwise lending as in each recurrent housing crisis in many a country.

Fraser, yet find himself unable to resist that pressure. Another however may resist this pressure, as was the case with Paul Volcker. Shocks arising from central bankers avoiding or incurring sharp interest rate hikes, and imposing or failing to impose banking regulations, are not random shocks in a system with a probabilistic distribution of outcomes known to all agents. Rather they are products of personality, of the particular heuristics each central banker employs in the complex situation of his network of friendships and conceptions of his duty and of how the economy operates.

The tense exchange rate situation of 2007–8 wherein the USD dramatically appreciated against the EURO is likewise of human making. As noted by the Italian member of the European Central Bank's board of directors, Lorenzo Bini Smaghi (2007), the ECB and the US Federal Reserve Board have between them full power to set this exchange rate.

The avoidance of the appreciation of the USD becoming drastic in late 2007 for the UK and Switzerland, and for the EURO and most other currencies in September 2008, was likewise a human decision. It was a decision of the US Federal Reserve Board chair Ben Bernanke to offer central bank credit swaps, and of other central banks to accept these, reversing in due course most of the USD appreciation. In this case however, it is an extraordinary fact that the US Federal Reserve Board did not contemplate the fact that the central bank swaps would have this benevolent effect, without which the rise in the USD would have created an altogether unmanageable strain on international financial system. It is an equally extraordinary fact that academic economists virtually failed to notice that the central bank swaps occurred at all. The swaps were initiated rather it seems to limit the flack that the US Federal Reserve Board would receive if US senators learned it had been helping foreign banks. The swaps transferred much of the aid to other central banks. For further details, see Pope and Selten (2011a, b, c).

In short, changes in the USD/EURO rate and in other exchange rates are not acts of nature, but due to human decisions, some with an eye to changing the exchange rate, others with a different goal in mind, so that the exchange rate changes are an incidental, even unconsidered outcome. McKinnon (2007) makes a similar observation that the choice of exchange rates rests with humans, not bolts of lightning from nature. His recommendation is that the cooperation should extend beyond the official sectors controlling the USD and the EURO, to those controlling the British pound, the Japanese yen and the Canadian dollar, i.e. to a five-way agreement to stabilise these key rates. In short, for any major developed country, the stylised fact is that all shocks come from human decisions. That is, the current practice of modelling shocks as exogenous, i.e. as emanating from nature, is a perverse modelling that is the reverse of the stylised facts.

### *3.1.5 Defect 5*

The heuristics that have to be employed by agents in any complex environment are ignored. Firms engaged directly in currency exchanges employ to a marked degree the heuristics of technical analysis. The heuristics can include standard prominent index heuristics such as Sharpe and Treynor ratios and Jensen's alphas. Technical analysis seeks to identify upper and lower barriers beyond which it is deemed to be unlikely that an exchange rate will move. These are barriers at which it is predicted

that there will be exchange rate turbulence, reversals of trends. The predictions can involve the judgment in discerning the patterns, in which case it is sometimes termed chartism. Alternatively the predictions can be mechanical, the product of fixed statistical rules. Exchange rate heuristics of traders are however largely ignored in the academic literature. Where any heterogeneity is incorporated, it tends to model traders as either informed (e.g. fundamentalist) or uninformed (e.g. random or chartist) profit maximisers in the case of static models, or in dynamic evolutionary models, as traders forming expectations according to rule 1 or (evolutionarily dominating) rule 2, e.g. Ahrens and Reitz (2005). Exceptions to maximising modelling examining such heuristics are starting to appear and include Neely (1997), Osler (2000, 2003).

As regards central banks, the authors are unaware of any non-maximising modelling that consciously incorporates commonly used official sector heuristics. Rather the norm is to model Taylor-rule maximising central banks. This is despite success levels from forecasting key variables via such theories being so poor that as observed in a report commissioned by the Bank of England, the optimising equation forecasts are improved by heuristics (ad hoc adjustments) and that it is a moot point whether a better exchange rate forecast would be to skip theoretical maximising equations and take the current exchange rate as the forecast, Pagan (2005). Econometrically Pope (1981, 1987) found private sector reactions more consistent with firms finding exchange rate uncertainty so great that they likewise took the current exchange rate as their estimate of the future exchange rate, a finding supported experimentally in Kaiser and Kube (2009).

The norm of ignoring these forms of evidence (that private and public sector agents alike use heuristics) does not mean that academic economists deduce behaviour under *genuine* maximisation. They are under conditions of pseudo (so-called) maximisation since deduced within an artificial world that has been simplified to the extent that algebra coupled with closed form solutions or simulations or econometric estimates can yield results. The simplifications are in fact drawn from a set of unacknowledged academic economists' heuristics. Academic economists' abstraction processes are in reality, heuristics processes, Pope et al. (2011a). The dependence of these so-called maximising models on the heuristics selected is revealed in the sensitivity of conclusions drawn as regards which, if any, equilibrium is attained and whether it is stable. In this regard, see e.g. Grandmont (1985), Chichilnisky (1999), Hahn (1999), Drèze and Herings (2003), Barnett and He (2002) and Dieci et al. (2006).

### *3.1.6 Defect 6*

There is widespread usage of representative agents models holding *so-called* rational expectations. These ignore heterogeneity of beliefs on how markets work, rendering them a farce even if coupled with learning. It is a farce since the question of what to learn is inadequately unaddressed, Phelps (1999). Such models lack rationality in that they ignore the non-stationarity of expectations.[7]

[7] Hendry, On the Mathematical Basis of Inter-temporal Optimization, Oxford University Economics Department Working Paper 497, http://www.economics.ox.ac.uk/Research/wp/pdf/paper497.pdf.

### *3.1.7 Defect 7*

The oft-remarked importance of friendships and enmities between central bankers, politicians, government officials and key private players tends to be omitted. Yet these emotional ties ensure shocks to the system whenever personnel changes in key posts occur, altering goals of both the official and private sectors.

## 3.2 Remedies

Remedying defects 1–3 is fairly straightforward, albeit doing this involves such complicated models that closed form solutions are essentially infeasible, as detailed in Part 5. Remedying features 4 to 7 is difficult to specify in any detail until more research is completed, and because some details are sufficiently idiosyncratic as to be unique. The particular model presented below is accordingly developed in two general versions.

One version enables a game theoretic solution since it substitutes for those tricky to specify details involved in features 4 to 7, the standard game theoretic assumption that all agents maximise their von Neumann-Morgenstern utility functions. Since utility maximisers generate no shocks, and since we are abstracting from the exceptional events of shocks from nature, this renders the model and its game theoretic solution determinate. In this determinate situation, only ordinal utilities are required for choices. Each agent's ordinal utility function is given by that agent's payoff (profit/objective) function.

The second version of our particular model drops this maximising assumption and allows for features 4 to 7. The means of including features 4 to 7 is via an experiment. In an experiment, these features do not need to be *pre*-specified, but are as executed by the experimental participants. The experimental set-up is that of Pope and Selten (2003). It was programmed by Sebastian Kube and Johannes Kaiser. The experimental sessions were conducted in 2003 and 2004 in the Bonn University Experimental Economics Laboratory. The participants were advanced economics students.

In summary, this paper's central bank conflict-cooperation theory of exchange rate determination addresses defects 1–7 as follows:

1 by limiting private sector influence to the region of exchange rate aim conflict between the central banks;
2 by including seven common objectives of official sectors;
3 by including five types of agents–governments, central banks, employer and employee wage bargainers, and firms–and by allowing the outcomes to arise from market power, instead of assuming that participants, contrary to fact, decide as if they have no market power;
4 by allowing the participants to determine the personal dynamics, and thus for the importance of these to be manifested in differences among sessions, each of which comprises different individuals;
5 by allowing participants to use their own heuristics to seek to attain their goals in this complex environment where the maximising "right thing to do" is unclear;
6 by allowing participants' heterogenous beliefs to enter their decisions
7 by limiting shocks to those generated by human decisions.

Within the central bank conflict-cooperation theory of exchange rate determination, different models can be constructed for different purposes.

## 4 Features of the model experimentally investigated

Within the central bank conflict-cooperation theory of exchange rate determination, the model experimentally investigated was devised to yield insights on the adoption of the EURO. It has two countries, each with its own currency, symmetric in every respect as regards the real economy, and thus suggestive of say Italy and Germany. In each country there is: one government, one central bank, one union representative, one employer representative, and five firms, all of which buy local and imported materials produced under competitive conditions (and thus made by a vast number of firms not represented by players in our laboratory). These imported materials are used in fixed proportions to produce a homogenous final good sold in a Cournot market,[8] with nominal demand set by the government as per Fig. 1.

As regards the financial side of real production, 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 act as their own financial intermediaries in any hedging or speculating that they do 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 have conflicted exchange rate goals.

### 4.1 Central bank intervention

If they have identical exchange rate aims, the two central banks set the exchange rate. Their unlimited power by legislation to produce their own currency precludes importing and hedging/speculative activities of the private sector from having any influence on the exchange rate.

In the event of a conflict between the exchange rate aims of the two central banks, the amounts of each country's central bank intervention to attain its exchange rate target depends on its import or exports price. It automatically intervenes up to a set proportion, $\xi_2$, 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 (termed a low aim conflict). It automatically intervenes up to a set proportion, $\xi_1$, 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 (termed a high aim conflict).

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),

[8] Field and empirical studies reveal that Cournot oligopolies with five or more participants have difficulty attaining systematic collusion, the lack of which, broadly speaking, characterises corporatist EURO bloc production. The European Economic Commission has been helpful in reducing the corporatist, collusive character of Europe over the past decades.

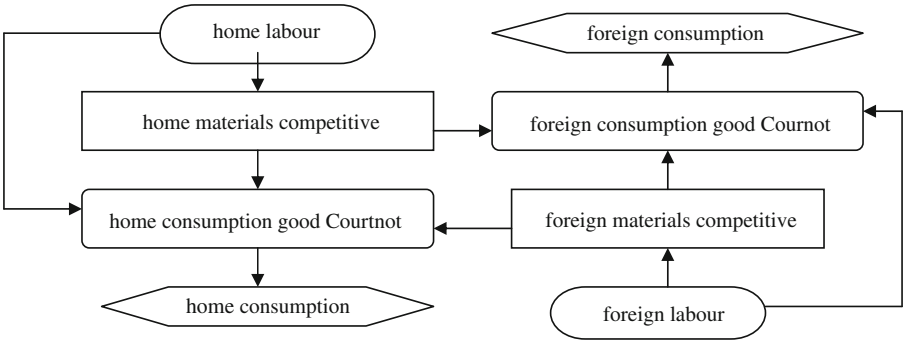


**Fig. 1** Commodity flows

$\xi_1 > \xi_2$. The actual exchange rate ensuing in these conflict situations is the ratio of offers made by both firms and central banks of each currency as long as this ratio is within the exchange rate aims of the two central banks. If this ratio lies outside the exchange rate aim of either central bank they cooperate to ensure that the *actual* exchange rate is the nearest of the two exchange rate aims to this ratio. The two central banks can achieve this since each has the power by issuing the requisite amount of their own domestic currency to avoid the *actual* ratio (exchange rate) lying in a region desired by neither of them.

### 4.2 Official sector tasks and instruments

In addition to the government setting nominal expenditure, the official sector, in the form of its central bank, sets its interest rate and announces its target price for the next period and its exchange rate aim. Thus 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 to meet its goals. In having the official sector short on instruments, we offer reasonable scope for the popular view to be demonstrated that adding an exchange rate change instrument helps macro-management.

The goals are 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 avoiding 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, with penalties for the official sector deviating from each of its goals as listed in Part 3 above.

### 4.3 Exchange rate targeting and shocks

As in the 1961 Mundell optimum currency area model, central banks 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 assumption of the existence of a single

shock, or else (in models that extend 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 models, the central bank knows perfectly the source of the shocks and exactly where the new equilibrium is. We replace these false assumptions about shocks and knowledge of the new equilibrium in our laboratory experiment, having instead all shocks generated by the domestic official and private sectors in the two countries. Thus in our laboratory set-up central banks and governments can be as fallible and error-prone as has been reported of actual central banks, e.g. the Bank of England in its exchange rate policy, Cobham (1994, 2002a, b, 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 and interest rate relative to the other central bank. Being also 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 fallible moves by members of the private and public sectors in the two countries, our experiment offers a fresh perspective on whether central banks really are able to use the extra instrument of the exchange rate to improve macroeconomic management, to restore equilibrium.

### 4.4 The private sector

Each central bank and government announces to all in both countries its decisions on aggregate nominal expenditure, on the interest rate and its target price for next period. In one treatment each official sector also announces its exchange rate target to all. This might lead to a moderation of exchange rate moves–to the exchange rate staying more toward the middle of the range between the two central bank goals. This could happen as often the interest rate incentive to shift funds will conflict with the exchange rate incentive indicated by the official sectors generating either smaller private capital flows or two-way counterbalancing flows.

In another less transparent treatment, exchange rate goal information is shared only with the other country's central bank. Here for the firms, the interest rate incentive is unconstrained by exchange rate information from the official sector. Thus private sector capital flows might more often tend to push the exchange rate largely toward the extreme of one central bank's goal, and this might in turn accentuate exchange rate instability.

After each official sector has set its four instruments, and made all or three of these instruments available as public knowledge, private sector decisions commence. First, in each country, the union and employer representative bargain over nominal wages. If an agreement is not reached after the set time allowed of 10 min, a strike ensues, with both negotiators receiving zero pay, a government set wage, and firms 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 from the lower wage determined in the case of a strike) is announced for both countries, firms decide. Firms decide 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 or speculate. The currency market

then operates, setting 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 firms' owners.

The union representative's payoff is real wages measured as nominal wages divided by the announced official sector target price. The payoff of the employer wage-bargaining representative, is proportional to the total firm profits share of total expenditure measured as the sum of the nominal profits of the five firms divided by total nominal expenditure. The payoff of each firm is its profits share of total expenditure measured as its nominal profits divided by total nominal expenditure.

## 5 Understanding complex models

We shall in Part 6 introduce the full details of our experimentally investigated model within the central bank conflict-cooperation theory in the form of an English translation of the instructions given to experimental participants. In part 6, we thus offer a model by a game's rules – not by an ivory tower discourse on assumptions of constrained motives. To see that remote abstract discourse may impair understanding, consider economists' squeamishness about survey–as distinct from market–evidence. Most economists adopt the revealed preferences dogma and deem that choices reveal people's motives, and so downplay findings from experiments based on "what do you think" compared to findings based on those that ask what would you choose. On the same revealed preferences logic, you the reader can acquire a deeper understanding of a model by asking, as an imaginary experimental participant, how you would choose in each role, imagining yourself in each of the varied roles that ensue. Having to think yourself into playing each role may entice a more vivid understanding of assumptions than when you read a model described in abstract formulations such as "Let there be $x$ …", or "There is an $x$ such that …"

To see how much more we can comprehend a model when placing ourselves within it, consider the fate of the Mundell (1961) model. This model continues to be frequently used to justify multiple currencies despite Mundell's objective elucidation to the contrary right back in that 1961 paper. Had the model instead been presented to readers as participant instructions, it is possible that even in that simple world of Mundell (1961), readers would have perceived disadvantages in multiple currencies. Imagining having to make the decisions oneself entices often a deeper appreciation of assumptions than simply reading that agents do $x$ and $y$ happens.

Presenting a model as instructions aids also in another respect. To choose, participants have to look at numbers to assess what is happening to each land–as do real-world official sectors, firms and so forth. The cognitive abilities and analytical methods assumed in purely algebraically presented models are veiled from us if we do not sit down as in reading the below instructions, and consider how on earth could someone decide given these sets of numbers and the payoff (profit/objective) function that we face in each role as that particular sort of public or private sector agent.

### 5.1 Complexity warnings

The particular model here presented in part 6 is light years more complex than either Mundell (1961) or its subsequent extensions. Bear in mind too that our model is far simpler than the real world. It had to be simple enough to be comprehensible for upper level economics students after an hour and 15 min of instructions–comprehensible enough for participants not to lose so much money by so many mistakes that the game had to be prematurely ended, negating up to 10 h of time invested by 18 participants and three supervisors. This indeed proved to be the case, in part through Sebastian Kube's expert participants' instructions sheets, and the elucidation of these to participants by Sebastian Kube and Johannes Kaiser. None of our nine sessions had to be abandoned for this reason, even if one firm's losses were very extreme. This of course reveals that our set-up is much less complex than that of the real world where giant multi-nationals and hedge funds continue to go into receivership due to exchange rate mistakes, and official sectors continue to lose billions of taxpayers' funds through their exchange rate mistakes.

In reality, payoff functions involve large margins of doubt adding to the complexity of evaluation and choice. Did, for instance, the UK Treasury guess how much of its power would be transferred to the Bank of England after its failed attempt to hold the pound in the early 1990s? Did Italian speculators dream that their bank accounts would be raided after the government's losses in an earlier failed attempt to resist an attack on the Lira? One of the simplifications of our set-up is that each participant knows exactly his payoff function. This allows the inferences made later in the paper concerning the effect of multiple currencies under the conventional finance assumption of choosers maximising their utilities.

However, the set-up is sufficiently complex to mimic a feature of the real world, namely that even were the agents to know their utility function exactly, essentially none could work out how to maximise it. There is thus a certain degree of comedy, as will be further discussed in Part 7, in reaching a conclusion on what a utility maximising agent would do. For the present, simply consider that economics routinely assumes maxima are costlessly and instantly calculable, and in each role in this set-up that is so much simpler than reality, consider if you the reader can discern the maximising act. Should you instead feel that you need to reach for heuristics to evaluate alternatives and reach a decision, then you conform to feature 5 of our alternative model. If your heuristics might differ from those of others, you conform also to feature 6 of our alternative model, and if you feel that you cannot fully anticipate what the next round will bring, you grant feature 7 of our alternative model, of shocks from human decisions.

## 6 The model in the form of participant instructions

This experiment has 18 participants.

There are two countries in the experiment

- country *A*
- country *B*

At the beginning of the experiment you will be randomly assigned to one of these countries.

In each of the two countries there are nine players with five different roles:

- government
- central bank
- labour union
- employers' association
- five firms

The firms are numbered from 1 to 5. Each country has its own currency. Your role in this experiment will be randomly assigned to you.

The game runs over several rounds. Each round consists of several steps:

- government decision
- central bank decisions
- wage bargaining between union and employers' association
- decisions of firms on production quantities
- decisions of firms on currency transactions

At the above five steps participants playing these roles make their decisions. Three further steps, calculated by the computer then follow:

- currency market: determination of the exchange rate
- round payments and determination of account balances
- transfer of the firm accounts

The steps in detail

In the following everything is described from the point of view of Country *A*. Everything is analogous for Country *B*. However, the value for Country *B* will be marked by an asterisk, *. Decisions are always made for the current round.

## 6.1 Government decisions

By means of fiscal policy, not modelled in detail, the government in each country determines that country's amount of total expenditure, *D* and *D**, respectively. This total expenditure is spent entirely on a consumption good produced by firms in that country.

## 6.2 Central bank decisions

Each central bank has to fix three decision parameters:

- *the interest rate*

  Note that 1 + interest rate = interest factor, *r* and *r**, respectively. Eg an interest rate of 8% corresponds to the interest factor 1.08. Firms can take short run loans and make short run money investments at this rate.
- *the target price* for the next round, $p_+$ and $p_+$*, respectively.

  This is the price that the central bank would like to see as the price for the domestic good in the next round. So the current target price *p* has been set in the prior round, and $p_+$ is now set for the next round.

– *the exchange rate aim*, $f$ and $f^*$, respectively.
  The exchange rate aim states how many units of own currency that the central bank would like to receive for one unit of the foreign currency. What is actually received after the exchange rate market operates, is the actual exchange rate, $e$ and $e^* = 1/e$, something not fixed by each central bank alone but is the result of the currency market's operation. The central banks intervene on the currency market to defend their exchange rate aims. This happens automatically and results in a final exchange rate $e$ between $f$ and $1/f^*$.

### 6.3 Wage bargaining between union and employers' association

In this step the union and the employers' association in each country negotiate the wage rate, $w$ and $w^*$, respectively, for the current round. This is done by exchanging text messages (chatting) and wage offers. These wage offers are not permitted to be lower than the official minimum wage, $w_0=0.14p$. Bargainers have 10 min for the wage negotiations. If no consensus is reached, there is a strike in that country. In the event of a strike, production capacity and demand are lower than normal in that round, and the wage rate is equal to the minimum wage rate $w_0$.

### 6.4 Decisions of firms on production quantities

Firms have to make two decisions. The first is to choose a quantity $Q_i$ (here $i$ is the number of the particular firm) of the consumption good to produce and sell. The maximum quantity is 60, but in the case of a strike, the maximum is 45. The minimum quantity is 20. Three inputs are needed for production:

– *Home raw materials*
  For one unit of the consumption good, one needs one unit of home raw materials purchasable on the home material market at a cost of $m = wr$. (This is because each unit of raw materials is produced with a unit of labour that costs $w$. Then interest paid on prepaid wages increases the total unit cost to $wr$.)
– *Foreign raw materials*
  For each unit of the consumption good produced a firm uses one unit of foreign raw materials, bought on the foreign material market at a cost of $m^* = w^*r^*$ in foreign currency.
– *Labour*
  Running a firm requires 15 units of labour plus 1 unit of labour for each unit of the consumption good produced. Workers can only be hired on the home labour market where the wage rate is $w$ per unit hired.

If one has decided to produce $Q_i$ units, then one needs:

– $M_i(=Q_i)$ units of home raw materials at a total cost of $M_i m$
– $M_i^*(=Q_i)$ units of foreign raw materials at a total cost of $M_i^* m^*$ in foreign currency
– $L_i$ units of labour with $L_i = 15 + Q_i$ at a total cost of $L_i w$

### 6.5 Decisions of firms on currency transactions

Each firm has a home account and a foreign account. All transactions are entered on the relevant account. Thus the home account is charged with the wage expenses $L_i w$ and the foreign bank account is charged with the costs $M^*_i m^*$ for foreign raw materials. The existence of two accounts makes currency transactions possible after the production quantity has been fixed.

*A firm can:*

- *offer home currency* $X_i$
  Here the firm takes a loan of $X_i$ at an interest inclusive cost of r from its home bank and for this it receives $X_i e^*$ in foreign currency. After earning foreign interest on this foreign currency, the firm has an amount of $X_i e^* r^*$ on its foreign bank account.
- *or offer foreign currency* $X_i^*$
  Here the firm borrows on its foreign account an amount $X_i^*$ at an interest inclusive cost of $r^*$. This money is then exchanged on the currency market and the firm receives $X_i^* e$ in home currency, on which it earns interest at the rate $r$ on its home bank account.
- *or offer no currency*
  This means not being active on the currency market

Take into consideration:

- A firm cannot offer both currencies at the same time
- The amount of currency transactions is limited by how much the firm decided to produce, since a firm must cover its costs for material, labour etc.
  The *maximum amount of home currency* a firm can offer is $(80\text{-}L_i)w$
  The *maximum amount of foreign currency* a firm can offer is $20w^*$
- When a firm offers a currency, it is not yet decided how many units of the other currency it will receive, since it does not get them at the exchange rate for the last round. The currency offers of all firms may have an influence on the exchange rate in the current round. The amount flowing to a firm account in the other currency is calculated at the exchange rate of the current round.
- At the end of the round, the balance on a firm's two accounts will show what it has earned, however, in the two different currencies. In the next round the firm's foreign account will be automatically offered at the currency market and will be exchanged to its own currency and this offer may again influence the exchange rate. The value of its foreign account balance in its home country currency will be determined by the currency market of the next round. A firm should pay attention to this in connection with its own currency transactions.
  If you are a firm, you can make use of a *profit calculator* as a decision support. Here you enter your exchange rate expectations for the current round and the next round, how much you want to produce, and what you expect the other four firms will produce together. On the basis of these expectations, the computer provides a table

with an adjustable scale. In this table you can see your profits obtained if all your expectations come true. At the same time the computer determines which currency you should offer if your exchange rate expectations turn out to be exactly correct.

### 6.6 Currency market

After all players have made their decisions for the current round, the currency market determines the current *exchange rate*. The exchange rate is not randomly determined, but depends on the decisions of the firms and the automatic interventions of the central banks. It is determined in such a way that the demand for a currency becomes equal to the supply of this currency.

The *supply* of home currency is composed of:

- The home currency offers of foreign firms (from their point of view the home currency is the foreign currency) and home currency offers of domestic firms (=$X$)
- Money amounts on the foreign accounts of foreign firms at the end of the preceding round, offered in this round, in order to exchange it into their domestic currency (=$K$)
- Possible interventions in home currency of the domestic and the foreign central bank (=$I$)

The *demand* for the home currency is composed of:

- The foreign currency offers of foreign firms (offers of domestic currency from their point of view) and foreign currency offers of home country firms (=$X$*)
- The monetary amounts on foreign accounts of home country firms at the end of the preceding period, offered in order to exchange it into home currency (=$K$*)
- Possible interventions in foreign currency of the domestic and the foreign central bank (=$I$*)

Therefore the preliminary exchange rate ê is determined by $X + K + I = \hat{e}\,(X^* + K^* + I^*)$

### 6.7 Central banks and the currency market

The above exchange rate is only preliminary, since the central banks intervene in two ways. At first, each central bank makes precautionary offers in order to defend its own exchange rate aim against that of the other central bank. However, these interventions are limited in the form of a dependence on the preceding round's material price, $m_$and $m\_$* respectively.

There can be two kinds of conflict:

- Each central bank wants a lower value for its own currency than the other bank does, i.e. $f > 1/f$*. In this case, the home country central bank offers $I$=600 $m\_$ of its home currency and the foreign central bank offers $I$*=600 $m\_$* of its currency.

– Each central bank wants a higher value for its own currency than the other central bank does, i.e. $f < 1/f^*$. In this case the home country central bank offers $I^* = 500\, m\_^*$ of the foreign currency and the foreign central bank offers $I = 500\, m\_$ of the home currency (the foreign currency from its point of view).

It is possible that the preliminary exchange rate $\hat{e}$ is outside the interval between the two exchange rate aims. In this case the two central banks cooperate in order to keep the exchange rate in this interval:

– If the preliminary exchange rate $\hat{e}$ is smaller than $f$ and $1/f^*$, then the final exchange rate will be the smaller of the two values, $f$ and $1/f^*$
– If the preliminary exchange rate $\hat{e}$ is greater than $f$ and $1/f^*$, then the final exchange rate $e$ is the greater of these two values.

If the preliminary exchange rate $\hat{e}$ is between $f$ and $1/f^*$ or at one of these values, then it is also the final exchange rate.

### 6.8 Round payoffs and account balances

In each round you receive a number of points, your round payoff, which depends on your decisions and those of the other participants and on your role. You are credited with these points on your payoff account, an account with a balance in points not usable as a resource in the game.

### 6.9 Account balances of firms and employers' associations

After each round, the account balances of each firm are transferred to its owners. The owners exchange accounts in foreign money to their home currency, but only in the next round. Therefore firms–as also employers' associations–obtain their payoffs for this round only in the next round. Firms and employers' associations receive the value of the domestic account plus that of the foreign account at next round's exchange rate. The domestic component plus the remitted foreign component together comprise the profit of a firm. The round payoff in points of a firm is its profit divided by total domestic expenditure, $D$ or $D^*$, respectively.

**Table 2** Development of account balances of firm $i$

| Home bank account | Foreign bank account |
|---|---|
| 0 | 0 |
| $-L_i w - X_i$ | $-X_i^*$ |
| $X_i^* e - L_i w - X_i$ | $X_i e^* - X_i^*$ |
| $r\,(X_i^*\, e - L_i\, w - X_i)$ | $r^*\,(X_i e^* - X_i^*)$ |
| $Q_i\, q + r\,(X_i^*\, e - L_i\, w - X_i)$ | $r^*\,(X_i e^* - X_i^*)$ |
| $Q_i q + r\,(X_i^* e - L_i w - X_i) - M_i m$ | $r^*\,(X_i e^* - X_i^*) - M_i^* m^*$ |
| 0 | 0 |

*6.9.1 Determination of account balances if you are a firm (see Table 2)*

– *Firm home bank account*

1) Wage payments and offers of home currency are deducted from your home bank account
2) If you have offered foreign currency, after the currency market has determined the exchange rate, you are credited on your home bank with the amount into which this converts in your home currency
3) This credit on your home bank account is multiplied up by the domestic interest factor
4) You are credited on your home bank account with the value of your sales (The determination of this value is described below)
5) The costs for domestic materials are deducted from your home bank account

Consequently, the final balance on your firm home bank account is

$$Q_i q + r(X_i^* e - L_i w - X_i) - M_i m$$

– *Firm foreign bank account*

1) If foreign currency is offered, the amount is deducted from your foreign bank account
2) If you have offered home currency, after the currency market has determined the exchange rate, you are credited on your foreign bank account with the amount into which this converts in your foreign currency
3) This credit on your foreign bank account is multiplied up by the foreign interest factor.
4) The costs of foreign materials is deducted

Consequently the final balance on your firm foreign bank account is

$$r^*(X_i e^* - X_i^*) - M_i^* m^*$$

The final balances on firm home and foreign accounts are transferred to the owners. Your profit for the current round is the sum of your final balance on each of these two accounts with the foreign balance evaluated in home currency at the exchange rate of the next round except in round 20, where it is evaluated at the exchange rate prevailing in that round.

*6.9.2 How sales are determined*

The total amount produced is always sold. However, the sales price $q$ depends on several factors. Normally the price $q$ is total domestic expenditure divided by total domestic production, i.e. $q = D/Q$

In the case of a strike, demand is decreased, and the price is lower, $q=0.6(D/Q)$

Once more we want to direct your attention to the profit calculator. It facilitates your decisions by making all these computations for you. It computes the price resulting from your prediction, deducts variable cost per unit for labour and materials,

and then computes your gross profits. The fixed labour costs for running firm are deducted from this. Since labour costs arise before interest is paid, the profit calculator also takes account of the opportunity costs arising thereby. In the fields of the table you can see your operating profit. This is *not* your payoff, but only the part of your profit due to your production decision.

### *6.9.3 Unions and employers' associations*

If agreement is not reached in wage bargaining, then there is a strike and you receive no payoff in this round. If, however, you agree on a wage rate, then you receive the following payoffs.

*Union*

Your success is measured by the wage rate divided by the current target price. You receive $U = w/p$

*Employers' association*

Your success only indirectly depends on the wage rate. You receive the sum $\Pi$ of profits in your country divided by the total expenditure, $V = \Pi/D$

Since the sum of profits will only be determined in the next round, you receive the payoff for this round in the next round.

### *6.9.4 Government and central bank*

You pursue several goals including price stability and adequate employment. Your payoff function is as follows.

$$B = 5 - 4\left(\frac{p_+}{p} - 1\right)^2 - 4\left(\frac{q}{p} - 1\right)^2 - 4(\mathrm{r} - 1.05)^2 - 2\left(\frac{m_-}{em_{-*}} - 1\right)^2 - 2\left(\frac{e}{f} - 1\right)^2 - .02|600 - L|_+ - .01|L - 720|_+$$

Here $L$ denotes total labour demand in your country, i.e. labour demand of domestic firms for production purposes (5*15 + $Q$) and the labour demand in the domestic materials industry ($M = Q + Q^*$).

The notation $|X–Y|_+$ has the following meaning

$$|X - Y|_+ = \max(0,\ X - Y)$$

Your payoff is at its maximum if you attain all of your seven goals.

### *6.9.5 Final payoffs*

After the end of the experiment you receive the sum of your points (your round payoffs) at a conversion factor depending on your role:

- as a government or central bank, you receive 1 Taler for 1 point
- as a union you receive 19.6875 Taler for 1 point
- as an employers' association you receive 50 Talers for 1 point
- as a firm you receive 250 Taler for 1 point

The number of Taler $x$ is then paid in euro according to the following rule

| *Sum in Taler between* | *Conversion into €* |
|---|---|
| 0 and 60 | $x$ |
| 60 and 100 | 60+0.5 ($x$–60) |
| 100 and 200 | 80+0.3 ($x$–100) |
| 200 and 300 | 110+0.2 ($x$–200) |
| over 300 | 130+0.1 ($x$–300) |

**Table 3** Example

| | | Land *A* | Land *B* |
|---|---|---|---|
| Values from the preceding round | material price in the preceding round $m_-$ | 2.666664 | 3.733338 |
| | actual target price $p$=that targetted for this round in the preceding round | 10 | 14 |
| Government | total expenditure $D$ | 2000 | 2800 |
| Central bank | interest rate $r$ | 1.05 | 1.05 |
| | next round's target price $p_+$ | 10 | 14 |
| | exchange rate aim $f$ | 0.71429 | 1.4 |
| Wage bargaining | strike | no | no |
| | wage rate $w$ | 2.53968 | 3.55556 |
| Firm 1 as example | production decision $Q_1$ | 40 | / |
| | home currency offer $X_1$ | 0 | / |
| | foreign currency offer $X_1$* | 0 | / |
| Firm decisions summed for the whole country | total home production | 200 | 200 |
| | total home currency offer | 0 | 0 |
| | total foreign currency offer | 0 | 0 |
| Materials industry | demand for materials $M$ | 400 | 400 |
| | materials price $m$ | 2.666664 | 3.733338 |
| Markets | final exchange rate $e$ | 0.71429 | 1.4 |
| | consumption goods price $q$ | 10 | 14 |
| Payoffs | home bank account of firm 1 | 146.66692 | / |
| | foreign bank account of firm 1 | −149.33352 | / |
| | payoff of firm 1 in this round if $e_+ = e$ | 0.02 | / |
| | union payoff | 0.253968 | / |
| | profit sum | 200 | / |
| | payoff of employers' association | 0.1 | / |
| | payoff of central bank | 5 | / |
| | payoff of the government | 5 | / |

Explanations:

/: not relevant here

Values with * e.g.: If you are in Country $A$, then the $D$ of Country $B$ is $D$* for you

Table 3 gives you an overview in the form of an example that we now work through. You can always look at your decisions in the preceding rounds. You start in an already existing world and thus in round 2 and you can see how the world functioned in the preceding round, round 1. This look back serves to orient you with examples of decisions that others took and might take again, and to reveal to you choices that you could take yourself, and to see what ensued (exchange rate, payoffs etc.) from such decisions. We now turn to a set of such decisions in the example below, and give you practice interpreting the decisions made in it by the governments, central bankers, employer and employee representatives, and firms.

## 7 Equilibria with utility maximisers

This first model is sufficiently complex that Reinhard Selten was unable to ascertain whether it had a game theoretic equilibrium or not. He needed to construct a new concept of an incomplete equilibrium whereby branches that could not improve payoff are not investigated. Under plausible selection criteria, the incomplete equilibrium that is symmetric as regards the real economy is, he demonstrated unique, and could be a reasonably traditional economic modelling benchmark, Selten (2003).

The need for a new equilibrium concept to derive a closed form solution and the need for deployment of selection criteria puts an element of comedy into equilibrating claims for exchange rates. The economist's notion of an exchange rate equilibrium is close to empirically empty when that economist can only discern it by ignoring the three distinctive features of this first model, issues 1 to 3 listed in the introduction. These three issues are the market power of co-operating central banks, the multiple and distinct goals of distinct agents, and the market power of key private sector players. Once we as economists exclude so-called rational expectations (that irrationally ignore these matters of market power and the different goals of different sorts of agents), we might think we can appeal to a game theoretic equilibrium instead. But as shown above, that appeal is in vain.

We can appeal to a new game theoretic incomplete equilibrium concept. We need more than that to have the equilibrium unique. We need also plausible selection criteria to render the symmetric game theoretic equilibrium unique. We need all these additional overlays to have a notion of equilibrium in a model that, even if complex, is far simpler than reality.

When we inspect this equilibrium's features, we find that once in an equilibrium, for utility maximisers, the equilibrium never changes, and the equilibrium involves keeping the exchange rate fixed, indicating no need for multiple currencies, as also no harm from having them either. There are no disequilibrating shocks. It might be objected that this is simply because our model lacks exogenous shocks. Indeed this is the case. The only scope for shocks in our model are endogenous ones, from people. Utility maximisers however create no shocks.

Let us then ask how to connect our model to the real world. Let us connect it to the shocks of the 1980s when Reagan's military expenditures and tax cuts for the wealthy combined with Volcker's tight monetary policy coincided with an unanticipated doubling of the US dollar. Let us connect our model also to the shocks of the drop in the US dollar vis-a-vis the EURO in the wake of the subprime crisis of 2007. Two

examples suffice. According to version 1, our model could not occur. Utility maximisers make none of the mistakes of people of the 1980s or of 2007.

To incorporate these shocks it might be thought that we need traditional models. But these real world shocks are patently caused by people's decisions, not by the meteors from outer space and other forms of random shock conventionally modelled. To incorporate the stylised fact that virtually all shocks to the exchange rates among developed countries are caused by people, we need version 2 of our model. We need to incorporate its features 5 to 7 that allow for individual personalities, their heuristics, their group dynamics and their mistakes. These are far too unknown and multitudinous for us to explicitly model. We get a fresh handle on them from our experimental results.

## 8 Non-maximisers causing shocks render equilibrium unspecified

Our participants were started in the symmetric equilibrium. The particular parameterisation for the central bank cooperation-conflict model of Pope and Selten (2003) employed in the experimental set-up is so simplistic that in this symmetric incomplete equilibrium, both consumer goods purchasing power parity and interest parity hold, whereas even in any reasonably realistic and complex neoclassical model, neither are predicted to hold in. Our participants thus were introduced to our experimental set-up displaying the simplistic features of an equilibrium exchange rate that conformed to both purchasing power parity and to interest parity.

Nevertheless, unlike the hypothetical utility maximisers of Part 5, our participants did not discern that they had started in equilibrium. Despite its unrealistic simplifications, our experimental set-up was so complex that there is no evidence of participants better discerning equilibria, their optima, by the 20th round either. In short there was no evidence of learning equilibria over time. Had for instance the government learned equilibria, it would have set is fiscal policy to accord with its previously announced fiscal policy. But this did not happen, which in turn meant that the equilibrium exchange rate conforming to purchasing power parity and interest rate parity is not even specified. This is rather as in the external world where private speculators and central banks alike exhibit little that is discernible as learning where an equilibrium exchange rate is, or even whether an equilibrium is specified. Today, despite 35 plus years of experience with floats, as when Bretton Woods dissolved in the early 1970s, private and public sector agents alike express puzzlement at unanticipated exchange rate changes.

Table 2 of Part 4 above on which participants learned the set-up for an hour and 15 min, and which pertains at the start of round 1, is the equilibrium. In equilibrium, expectations are fulfilled. Thus the consumer goods actual price must be for countries $A$ and $B$ respectively $p$ and $p^*$, i.e. the consumer price level announced by the central bank as its target for this round in the preceding round. Fiscal policy sets $D$ and $D^*$, respectively the nominal demand in countries $A$ and $B$, and thereby influences the *actual* consumer price level pertaining in each country. In each country the government announces its fiscal policy prior to the central banks setting their exchange rate aims. Hence for the equilibrium exchange rate to be specified, let alone selected as the aim of both central banks, one pre-requisite is that fiscal policy in each round in both

countries must be selected to be compatible with its country's already in the prior round announced central bank's target price, respectively $p$ and $p^*$.[9]

For round 1, for countries $A$ and $B$ respectively $P=10$ and $p^*=14$ are as given in Table 2 above, as are the equilibrium values for fiscal policy of D and D*. These are respectively, $D=200P=2{,}000$ and $D^*=200p^*=2{,}800$. In round 1, only two of the sessions had a pair of governments that chose these equilibrium fiscal policy values. The degree of deviation from equilibrium of the government in country B in session 1 was 79%. The average deviation from the equilibrium fiscal policy in round 1 over all sessions was 12%. Thus in the entire 9 sessions, only two, sessions 7 and 8, had pairs of governments that set equilibrium values for their fiscal policies, and thereby allowing the equilibrium exchange rate to be specified. For the other sessions, no action of central banks can be classified as equilibrating or non-equilibrating. See Table 4.

As regards the exchange rate, in equilibrium, purchasing power parity holds for consumer goods, and interest parity also holds. From Table 5, for country A, the equilibrium purchasing power parity choice of a value for $f$, its exchange rate aim, where specified by compatible fiscal policy, is, $p/p^*=0.71429$ as regards the number of units of its own currency needed to buy a unit of country B's currency. For country B the equilibrium value of its exchange rate aim $f^*$, where specified, is its reciprocal. But in sessions 7 and 8, for whom the equilibrating choice of exchange rate aim is specified, the central banks chose non-equilibrium exchange rate aims. The exchange rate aims in sessions 7 and 8 are incompatible with both consumer goods purchasing power parity in equilibrium, and interest parity in equilibrium. Table 5 details their deviations from the purchasing power equilibrium exchange rate aim. It also details the deviations of the other sessions from what their central banks should have chosen–had equilibrium been specified. The average absolute deviation from $p/p^*$in this first round was 15%.

Each of the 9 sessions contained different participants and so constituted one independent observation, as regards computing significance. Our nine independent sessions each of 20 periods means that we have a huge advantage over field data with its time series and cross sectional interdependencies. Our field data stem from a single world and a single history, rendering it tricky, to say the least, to decode the effects of shocks. Our nine independent sessions, nine world histories thus permit us insights into what is unique in actual world history, namely the role of individual personalities resulting in different heuristics used to cope with a complex situation.

In Table 5, it can be seen that the inter-session divergence from purchasing power parity was marked, from under nil to a massive 75%, indicating how crucial personality and group dynamic influences are. Nothing else differs in each session. In each session for each agent in a given role, there is the identical institutional and economic set-up and each has an identical utility function. Under traditional modelling their choices ought be identical. Econometrics, limited by a single world history, cannot discern what is here discerned, namely the extreme impact of personalities on choices made when the situation is too complex for anyone to engage in the maximising calculations posited in traditional neoclassical and game theoretic models.

[9] To constitute an equilibrium not only the exchange rate and fiscal policy choice, but also the selected interest rates, exchange rate aims, wage rates, production quantities and currency offers must also be at their equilibrium values.

**Table 4** Fiscal policy choices $D$ and $D^*$ of governments in countries $A$ and $B$ in round 1 (each stated in own currency)

| Session | Country $A$ | | | Country $B$ | | | |
|---|---|---|---|---|---|---|---|
| | Actual $D$ | Equilibrium $D$=200p and p is 10 | Deviation of $D$ from its equilibrium | Actual $D^*$ | Equilibrium $D^*$=200p* and $P^*$ is 14 | Deviation of $D^*$ from its equilibrium | Average absolute deviation from equilibrium |
| 1 | 2000 | 2000 | 0.00% | 600 | 2800 | −78.57% | 39.29% |
| 2 | 1990 | 2000 | −0.50% | 2800 | 2800 | 0.00% | 0.25% |
| 3 | 2050 | 2000 | 2.50% | 2850 | 2800 | 1.79% | 2.14% |
| 4 | 1000 | 2000 | −50.00% | 2820 | 2800 | 0.71% | 25.36% |
| 5 | 2100 | 2000 | 5.00% | 2750 | 2800 | −1.79% | 3.39% |
| 6 | 2200 | 2000 | 10.00% | 2000 | 2800 | −28.57% | 19.29% |
| 7 | 2000 | 2000 | 0.00% | 2800 | 2800 | 0.00% | 0.00% |
| 8 | 2000 | 2000 | 0.00% | 2800 | 2800 | 0.00% | 0.00% |
| 9 | 1500 | 2000 | −25.00% | 2400 | 2800 | −14.29% | 19.64% |
| Overall average | 1871 | 2000 | −6.4% | 2424 | 2800 | −13.4% | 12.2% |

A round is the above sequence of decisions and their outcomes played by both the official and private sectors. A round was played by the same participants 20 times, with a lunch break, typically after the 8th period. By round 20, governments in countries $A$ and $B$ have had 19 prior periods in which to learn to set their equilibrium fiscal policy at $200p$ and $200p^*$ respectively, where $p$ and $p^*$ are as announced by their country's central bank for round 20 in prior round 19. Table 6 reveals that by round 20, divergence of their fiscal policy decisions from equilibrium

**Table 5** Central bank exchange rate aims in round 1

| Session | $f$ exchange rate aim of country $A$ | $1/f^*$ exchange rate aim of country $B$ | Deviation of country $A$ from $p/p^*$ of 0.71429 | Deviation of country $B$ from $p/p^*$ of 0.71429 | Absolute average deviation from $p/p^*$ |
|---|---|---|---|---|---|
| 1 | 1.000 | 0.667 | 40.00% | −6.67% | 23.33% |
| 2 | 0.800 | 0.714 | 12.00% | 0.00% | 6.00% |
| 3 | 0.750 | 1.250 | 5.00% | 75.00% | 40.00% |
| 4 | 0.900 | 0.714 | 26.00% | 0.00% | 13.00% |
| 5 | 0.850 | 1.000 | 19.00% | 40.00% | 29.50% |
| 6 | 0.720 | 0.714 | 0.80% | 0.00% | 0.40% |
| 7 | 0.720 | 0.714 | 0.80% | 0.00% | 0.40% |
| 8 | 0.850 | 0.833 | 19.00% | 16.67% | 17.83% |
| 9 | 0.705 | 0.714 | −1.30% | 0.00% | 0.65% |
| Overall average | 0.811 | 0.813 | 13.50% | 13.90% | 14.57% |

**Table 6** Fiscal policy choices of governments in round 20

| Session | $P$ | Actual $D$ | Equili-brium $D$=200P | Deviation of $D$ from its equilibrium | $p^*$ | Actual $D^*$ | Equilibrium $D^*$=200$p^*$ | Deviation of $D^*$ from its equilibrium | Average absolute deviation from equilibrium |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 7 | 3750 | 1400 | 167.86% | 10.5 | 3350 | 2100 | 59.52% | 113.69% |
| 2 | 12.3 | 2700 | 2450 | 10.20% | 12.5 | 2850 | 2500 | 14.00% | 12.10% |
| 3 | 10.3 | 2100 | 2060 | 1.94% | 12.5 | 2850 | 2500 | 14.00% | 7.97% |
| 4 | 16 | 3000 | 3200 | −6.25% | 16.0 | 3000 | 3200 | −6.25% | 6.25% |
| 5 | 10.8 | 2150 | 2160 | −0.46% | 13.0 | 2572 | 2600 | −1.08% | 0.77% |
| 6 | 11.2 | 2500 | 2240 | 11.61% | 11.5 | 2300 | 2300 | 0.00% | 5.80% |
| 7 | 10.6 | 2400 | 2120 | 13.21% | 15.4 | 3500 | 3080 | 13.64% | 13.42% |
| 8 | 14.5 | 3000 | 2900 | 3.45% | 19.0 | 2700 | 3800 | −28.95% | 16.20% |
| 9 | 12.1 | 2100 | 2420 | −13.22% | 11.5 | 2200 | 2300 | −4.35% | 8.79% |
| Overall average | 11.6 | 2633 | 2328 | 20.90% | 13.5 | 2814 | 2709 | 6.70% | 20.60% |

had become more widespread and on average nearly twice as marked as in round 1. The average absolute deviation had risen from 12 to 20%.

For not a single session did a pair of governments select equilibrium fiscal policies. Thus not even in a single session is the equilibrium exchange rate specified. In session 1, this deviation was extreme, over 100%. Only in one session, session 5, was the deviation from equilibrium modest.

Table 6 reveals that by round 20, there was not a single session for which the equilibirum exchange rate was specified. By round 20 also, deviation from that indicated by purchasing power parity in the form of $p/p^*$was about as marked for every session. The sessional average deviation from $p/p^*$had fallen only from 12% to 11%. The minimum deviation had more than doubled, from 0.4% to over 1%, and the maximum deviation had risen a little, from under 24% to over 27%. See Table 7.

**Table 7** Central bank deviations from $p/p^*$ in round 20

| Session | Exchange rate aim f of country $A$ | Exchange rate aim 1/$f^*$ of country $B$ | $p/p^{**}$ | Deviation of country $A$ from $p/p^*$ | Deviation of country $B$ from $p/p^*$ | Absolute average deviation from $p/p^*$ |
|---|---|---|---|---|---|---|
| 1 | 0.900 | 0.833 | 0.6667 | 35.00% | 25.00% | 30.00% |
| 2 | 0.850 | 0.909 | 0.9800 | −13.27% | −7.24% | 10.25% |
| 3 | 0.900 | 0.833 | 0.8240 | 9.22% | 1.13% | 5.18% |
| 4 | 0.889 | 0.879 | 1.0000 | −11.10% | −12.13% | 11.61% |
| 5 | 0.840 | 0.840 | 0.8308 | 1.11% | 1.15% | 1.13% |
| 6 | 0.992 | 0.992 | 0.9739 | 1.86% | 1.86% | 1.86% |
| 7 | 0.720 | 0.720 | 0.6883 | 4.60% | 4.67% | 4.64% |
| 8 | 1.200 | 0.714 | 0.7632 | 57.24% | −6.40% | 31.82% |
| 9 | 1.100 | 1.000 | 1.0522 | 4.55% | −4.96% | 4.75% |
| Overall average | 0.932 | 0.858 | 0.864 | 9.90% | 0.34% | 11.25% |

## 9 Non-maximisers causing shocks in the form of central bank conflicts

Since the ratio 1/*f** transforms country B's central bank aim into comparable currency units to those of the exchange rate aim announced by country A, were there no conflict in exchange rate aim, this inverse would be equal to *f*, the exchange rate aim of country A's central bank. But in failing to maintain the equilibrium exchange rate goal in the first round, Table 8 shows that in every one of the nine sessions, conflict occurred right at the beginning, in round one, between the exchange rate aims of the pair of central banks. The overall average level of conflict was in the range of 16–17%. The degree of conflict varied markedly, from under 1% to over 66%. The institutional and economic set-up and the utilities for agents in each role were identical across sessions. The explanation thus for these differential degrees of conflict lies in differences in individual heuristics and in the group dynamics engendered in complex situations. None of the conflict, and hence also none of the variation in degree of conflict, is explicable with standard modelling.

By round 20, central bankers have had 19 prior periods in which to learn from each other, from their governments and from the behaviour of the private sector in response to their exchange rate aim decisions. Table 9 shows that, compared to round 1, by round 20, divergence of central bank aims from equilibrium was more marked for every session. The sessional average deviation from equilibrium had risen from 12% to 23%. The minimum deviation had more than doubled, from 0.4% to over 0.8%, and the maximum deviation had risen from under 24% to over 41%. By round 20, the degree of conflict between central banks had abated in most sessions, and was down on average from over 19% to now just over 11%. However 11% is still substantial, and in one session, conflict had escalated to 68%.

In short, Table 9 reveals that central bankers often became more cooperative with repeat interaction. By round 20, the results also reinforce the findings of round one, that individual differences matter. By round 20 it is evident that group dynamics serve to reinforce, not eliminate, the central role of individuals and their idiosyncratic heuristics for dealing with complexity. The average degree of conflict in exchange

**Table 8** Central bank exchange rate conflicts in round 1

| Session | *f* exchange rate aim of country *A* | 1/*f** inverse of exchange rate aim of country *B* | The extent of conflict from the viewpoint of country *A* \|*f*-(1/f*) *f*\| | The extent of conflict from the viewpoint of country *B* \|*f*-(1/*f**)\|/(1/*f**) |
|---|---|---|---|---|
| 1 | 1.000 | 0.667 | 33.33% | 50.00% |
| 2 | 0.800 | 0.714 | 10.71% | 12.00% |
| 3 | 0.750 | 1.250 | 66.67% | 40.00% |
| 4 | 0.900 | 0.714 | 20.63% | 26.00% |
| 5 | 0.850 | 1.000 | 17.65% | 15.00% |
| 6 | 0.720 | 0.714 | 0.79% | 0.80% |
| 7 | 0.720 | 0.714 | 0.79% | 0.80% |
| 8 | 0.850 | 0.833 | 1.96% | 2.00% |
| 9 | 0.705 | 0.714 | 1.32% | 1.30% |
| Overall average | 0.811 | 0.813 | 17.1% | 16.43% |

**Table 9** Central bank conflict in round 20

| Session | $f$ exchange rate aim of country $A$ | $1/f^*$ inverse of exchange rate aim of country $B$ | The extent of conflict from the viewpoint of country $A$ $(f\text{-}1/f^*)/f$ | The extent of conflict from the viewpoint of country $B$ $(f\text{-}1/f^*)/(1/f^*)$ |
|---|---|---|---|---|
| 1 | 0.900 | 0.833 | 7.41% | 8.00% |
| 2 | 0.850 | 0.909 | 6.95% | 6.50% |
| 3 | 0.900 | 0.833 | 7.41% | 8.00% |
| 4 | 0.889 | 0.879 | 1.15% | 1.17% |
| 5 | 0.840 | 0.840 | 0.04% | 0.04% |
| 6 | 0.992 | 0.992 | 0.01% | 0.01% |
| 7 | 0.720 | 0.720 | 0.06% | 0.06% |
| 8 | 1.200 | 0.714 | 40.48% | 68.00% |
| 9 | 1.100 | 1.000 | 9.09% | 10.00% |
| Overall average | 0.932 | 0.858 | 8.1% | 11.3% |

Note that each country's exchange rate is expressed as the number of domestic currency units required to purchase a unit of the other country's currency, and hence that in equilibrium, each country's central bank goal is the reciprocal of that of the other central bank's equilibrium exchange rate, and thus that in the absence of conflict, $1/f^* = f$

rate aim in this first period was 20%. The inter-session variation in degree of conflict was extreme, from 0.8% up to nearly 67%, again indicating the crucial role of individual personalities resulting in different heuristics used to cope with a complex situation.

Conflict between central banks was not merely the norm in the opening and closing rounds, but throughout, as can be seen from Table 10.

The findings of Tables 4, 5, 6, 7, 8,9 and 10 endorse the need to shift to models like that of Pope and Selten (2003) in putting in the forefront, the role of central bank cooperation and conflict together that of the personalities of those in key roles of

**Table 10** Overview of conflicts in central bank aims during the entire 20 rounds

| Session | Rounds in which there was a conflict | |
|---|---|---|
| | Total number | % of all rounds |
| 1 | 18 | 90.00 |
| 2 | 20 | 100.00 |
| 3 | 20 | 100.00 |
| 4 | 20 | 100.00 |
| 5 | 20 | 100.00 |
| 6 | 20 | 100.00 |
| 7 | 14 | 70.00 |
| 8 | 20 | 100.00 |
| 9 | 12 | 60.00 |
| Overall average | >18 | 90.00 |

private and public sector market power. It is inappropriate as at present to ignore the *non*-equilibrating conflict-cooperation strategies of central bankers in analysing exchange rate determination.

The findings of Tables 4, 5, 6, 7, 8,9 and 10 do not imply, however, that firms are irrelevant to the exchange rate derived for the particular parameterisation of the central bank conflict-cooperation model of Pope and Selten here investigated. To the contrary, the more conflict there is between central banks, as in reality, the more scope there is for firms' investment (hedging and speculative) activity–together with their payments for goods–to influence the exchange rate outcome. The extent to which the firms in total press with their exchange rate offers toward the direction of one of the two conflicted central banks determines the final exchange rate.

Where firms' joint capital and current account activities do not too markedly favour the aims of one or other of the two conflicted aims of the central banks, the resultant exchange lies *between* the conflicted aims of the central banks. Such a situation was however infrequent. The firms however generated one *between* these two aims, on average only a bit under 12% of the time. In every session, the norm was for the firms' joint capital and current account activities to markedly pressure for an exchange rate in the direction of one of the two centrals banks. The supply and demand pressure of the private sector was extremely uneven, to the extent that, without further central bank response, it would have pushed the exchange rate further than the aim of the central bank being endorsed by this private sector pressure. See Table 11.

The exchange rate in such circumstances was only kept to that of the central bank whose aim was more in line with that of the private sector pressure by *additional cooperative action of the pair of central banks*. Again, recall the legal power of central banks to print their own currency and offer it on the exchange market. In turn this implies that no private speculator has the power to countermand such joint cooperative central bank intervention.

**Table 11** Firm influence on the exchange rate

| Session | Rounds in which firms generate a compromise exchange rate between the conflicted central banks | |
|---|---|---|
| | Total number of rounds | % of rounds |
| 1 | 2 | 10.00 |
| 2 | 3 | 15.00 |
| 3 | 2 | 10.00 |
| 4 | 2 | 10.00 |
| 5 | 2 | 10.00 |
| 6 | 1 | 5.00 |
| 7 | 1 | 5.00 |
| 8 | 7 | 35.00 |
| 9 | 1 | 5.00 |
| Overall average | 2.333 | 0.117 |

In the central bank cooperation/conflict model of Pope and Selten (2003) here experimentally investigated for a particular parameterisation, this logical implication of powers of central banks to print their own currencies is honoured. Prior models have focussed on the media advertised role of the private sector, and have been swayed by Friedman's accounts in which the central banks can be ignored. In reality, the private sector does matter, but only to the extent of whether the resultant exchange rate is in the compromise range of the two central banks' aims, or at a boundary, the aim of one of that pair of central banks.

Our experimental results thus serve to highlight the crucial but overlooked matter of central bank cooperation and conflict. They serve also to delineate the extreme difficulties in modelling this in a manner to yield predictions. The differences among sessions underscore the necessity of knowing fine details of the heuristics of different personalities and group dynamics.

The results from employing the experimental design of Pope and Selten (2003) to an investigation of central bank behaviour tells decisively against equilibrating maximising modelling of central bank behaviour. As central bankers humbly report in reality, they do not use maximising decisions, and as our results show, when the discernment of equilibrium is beyond human ability, central bankers do not somehow miraculously manage to drive exchange rates into equilibria. Our results concerning central bank behaviour suggest that central bankers can increase their cooperation over time so long as the set of personalities in the private and public sector stays constant, but not in an equilibrating direction, and only to a moderate degree. In reality, there is a flux of public and private sector personnel so that our findings of increasing cooperation over time cannot be taken to be the norm in the external world, only a possibility that is occasionally realised. It happened in the middle 1880 s, and happened again with the central bank currency swaps initiated in the global financial crisis of 2007–2009 by the US Federal Reserve Board.

A single world money avoids the shocks caused by the disequilibrating actions of central bankers–and the international conflicts that arise from the typical situation, central banks with conflicting aims. These conflicts have been dangerously sharp in the case of those between Japan first then China on the one hand and other key currencies. There have also been conflicts at times since the onset of the global financial crisis, between the US and the EURO bloc. Advocates of a single world money include Mundell, not only in his writings of this millennium, e.g. Mundell (2003), but also back in Mundell (1961), and others such as Bonpasse (2006).

## 10 Other applications of the model

The experimental data garnered from the particular model of Pope and Selten (2003) within the central bank cooperation and conflict theory has also shed light on other issues. One set of issues concern firm behaviour in the face of exchange rate uncertainty, Kaiser and Kube (2005, 2009). A second set of issues concern how official sectors had significantly more success in maintaining international competitiveness with a currency union, and better overall success in their macromanagement, Pope et al. (2008). A third set of issues concerns the less violent fluctuations, and less risk of outliers achieved with a managed float including inter-

country objectives for the exchange rate and for international competitiveness than under the isolationist objectives of inflation targetting clean floats, Pope and Selten (2011a, b).

More generally, complexity effects indicate the value of modelling, as in this paper's model, within the umbrella of SKAT, the Stages of Knowledge Ahead Theory of Pope (1983, 1996/7), Pope et al. (2006/7; 2009) and Pope and Selten (2010/2011, 2011a, b). Complexity renders non-trivial the various stages through which a chooser progresses before the risk and uncertainty is resolved.

In this paper's model and experimental set-up, the focus is on the evaluation stage before reaching a decision. The difficulties of evaluating and reaching a good decision in a complex world made even more complex by variable exchange rates result in better macro-management without variable exchange rates. The difficulties in modelling how people generate shocks through their idiosyncratic heuristics and mistakes in the evaluation stage is part of the reason for economists mis-modelling shocks as simpler in origin–and in the process misconstruing exchange rates as equilibrating.

Economic theorists are fond of simplicity in models for elegance and tractability. Experimentalists are fond of simplicity that enables them to check and frequently reject the simple algebraically tractable mainstream theories. For science to progress however we need to progress beyond discovering that the simple maximising models of mainstream economics are false. As Hendry and Mizon (2010) offer a constructive algebraic econometric alternative to these false maximising models, we here offer a constructive non-algebraic non-econometric alternative. We offer it on one key policy issue, choice of exchange rate regime. In putting our Central Bank Conflict-Cooperation Model of Exchange Rate Determination into the public arena we introduce readers to a new perspective on exchange rate determination. We encourage readers to use this new tool to investigate exchange rate issues with the model as is. It overcomes the seven serious problems identified in our introduction.

The central bank conflict-cooperation model here presented can be used as a bank game for assessing exchange rate effects. Banks and universities can also use it as an instruction tool in helping participants to get a handle on the complex world of variable exchange rates. Control experiments with only a single central bank assist in delineating events without variable exchange rates and their attendant uncertainties.

## 11 Other models within the central bank conflict-cooperation theory

Researchers can modify the basic model of Pope and Selten (2003) prior to experimental use in order to test parameter sensitivity or variations in the exchange rate regime by

- enlarging or contracting the set of official sector objectives,
- altering central bank transparency concerning their exchange rate goals
- increasing the difficulty of central bank cooperation by introducing more currencies (introducing reserve currency complexities)[10]

[10] This allows for the complexities of a reserve currency that enter naturally once the number of currencies exceeds two.

- increasing the difficulty of private sector leveraging activity, collusion, and market cornering by altering banking regulation.[11]
- allowing for investment in production, distribution, advertising and in stocks of storable commodities including currencies[12]

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[11] These could include studies of how regulatory changes alter capital market imperfections influencing foreign investment, as in Froot and Stein (1991) and Dunning (1998).

[12] Shifting to a more full-fledged modelling of currencies as assets (rather than having the equilibrium exchange rate dependent only on interest rates in two currencies), and the inclusion of non-currency assets would permit more elements of the portfolio approach to exchange rate determination. But within the umbrella of this paper's central bank conflict-cooperation theory of exchange rates, these multiple asset influences would enter in a radically different manner from that in neoclassical growth exchange rate models such as that of Welfens (2008).

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