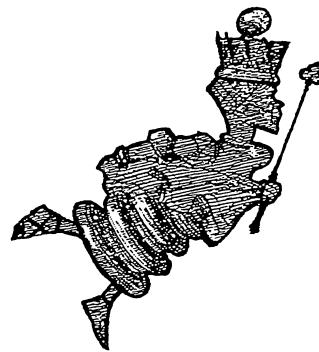




**Centre for Economic Learning
and Social Evolution
(ELSE)**



Activities 1995 – 2002
A Report for the ESRC
Annexes



**Centre for Economic Learning
and Social Evolution
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Annex A: Research Projects

1. Evolutionary Approaches

Project 1.1: Stochastic Evolution and Equilibrium Selection in Games

Aims and Objectives: Many models in economics and related social sciences describe strategic interactions, i.e. “games”. Such games often have many equilibria all of which are consistent with the agents rationally pursuing their self-interest. This project investigates whether processes of gradual biological or cultural evolution are more likely to lead to some equilibria than to others. We thus investigate “evolutionary equilibrium selection”.

Researchers: Binmore (ELSE), Seymour (ELSE), Vaughan (ELSE), in collaboration with Samuelson (Wisconsin).

Funding: ELSE’s core funding has supported Seymour and Vaughan's research through teaching buyouts. The project has also received support from the Leverhulme Trust through Binmore’s funding as Leverhulme research professor.

Duration: 1995-2005

Results: Not so long ago, economists were still trying to solve the equilibrium selection problem by inventing more and more elaborate definitions of what counts as rational behaviour, the idea being that some equilibria could then be identified as more likely to occur than others. More recently, not least as a consequence of the work of one of ELSE’s founders, Ken Binmore, these refinement theories have been abandoned in favour of a more practical approach in which predictions about which equilibria will be played are based on explanations of how real people might find their way to an equilibrium of a game by a process of trial-and-error learning.

Our work in this area builds on discoveries due to Kandori, Mailath, Rob, and Young (KMRY). They showed that stochastic models of evolution predict that for certain simple games, in the long run agents will settle down to play an equilibrium, and, moreover, some equilibria are much more likely than others. This is the key result that makes the theory of stochastic evolution useful for a study of equilibrium selection. Our work in this area has been aimed at extending KMRYs’ work. We have sought to extend the class of games to which the results apply, and we have studied the robustness of the results to changes in the model specification.

One problem affecting the predictions of KMRY is that they are very long-run predictions. The systems which KMRY describe will first find their way to some particular equilibrium of the game, then will be moved out of that equilibrium by some random shocks, will then move to a different equilibrium, from which random

shocks move the system again, and so on. Only in the very long run, when counting which equilibria were visited more frequently, will the KMRV prediction of equilibrium selection emerge.

In a joint research effort, Binmore and Vaughan, together with Larry Samuelson from the University of Wisconsin, have studied what they call the long-run predictions of a stochastic model. By this they mean the prediction obtained by looking at the first equilibrium that a system visits. They find that the deterministic replicator dynamics serves as a good predictor of this long-run outcome when the stochastic perturbations are sufficiently small (Binmore, Samuelson and Vaughan, 1995; Binmore and Samuelson, 1997).

Binmore, in joint work with Samuelson, has sought to extend the scope of the KMRV analysis to extensive games. Games that are genuinely realistic always have some dynamic structure, and one therefore needs to study their extensive form. In such games, there are typically an infinite number of equilibria, because the strategic behaviour specified by the equilibrium path is not fully determined. This behaviour is therefore liable to drift. Eventually, such drift in off-the-equilibrium-path behaviour may reach a point that destabilizes behaviour on the equilibrium path. Binmore and Samuelson (1999) exploit this phenomenon to study the circumstances under which a variety of different types of equilibrium may be able to survive.

A project by Vaughan takes a different approach to ‘evolutionary equilibrium selection’. The aim of this analysis is the construction of a distributional model that enables the study of the evolutionary dynamics that arise for symmetric games, and the equilibrium selection mechanisms that originate from such processes. The evolution of probability distributions over the state variables was studied using the Fokker-Planck (FP) diffusion equation associated to a stochastic version of the standard, continuous-time replicator dynamics. Equilibrium selection using the “basin of attraction” approach, and a selection process suggested by Pontryagin are contrasted. A first paper using this approach was presented at the Seventh World Congress of the Econometric Society, Tokyo, 1995.

An extension of this project by Seymour and Vaughan concerns the analysis of equilibrium selection in asymmetric games based on the same approach. However, they have obtained only limited results from an analytic approach. A computer programme has been developed to numerically solve the FP equation for arbitrary 2-player, 2-strategy games with numerical payoffs. Output consists of a probability distribution over pairs of mixed strategies for the two players. The low-noise limit shows condensation of probability mass at a single, selected equilibrium.

Dissemination: *Prominent publications* include: Binmore, Samuelson and Vaughan (*Games and Economic Behaviour*, 1995); Binmore and Samuelson (*Journal of Economic Theory*, 1997); Binmore and Samuelson (*Review of Economic Studies*, 1999). *Key presentations* include a large number of seminar presentations by Binmore, and Vaughan’s presentation at the Seventh World Congress of the Econometric Society, Tokyo, 1995.

Project 1.2: Mathematical Models of Evolution

Aims and Objectives: This project investigates mathematical models of evolutionary and learning approaches to games and society. The aim is to show that such approaches provide an understanding of social science issues that overturns conventional wisdom in many areas by telling us when and why the theory of rational behaviour performs quite well, and when and why it does not.

Researchers: Binmore (ELSE), Matros (ELSE), Seymour (ELSE), Vaughan (ELSE), in collaboration with Samuelson (Wisconsin).

Funding: ELSE's core funding has supported Seymour and Vaughan's research through teaching buyouts. Matros is a fully funded ELSE post-doctoral research fellow. The project has also received support from the Leverhulme Trust through Binmore's funding as Leverhulme research professor.

Duration: 1995-2005.

Results: This project investigates mathematical models of biological and social evolution. Much work in this area has, of course, been done in the past by mathematical biologists. However, much remains to be done until the theory really covers the variety of situations to which evolutionary theory can potentially be applied.

One interesting discovery from this line of research is that similar mathematics arise from a variety of apparently different hypotheses. In particular, simple models of learning by imitation of others ("social evolution"), and simple models of gene inheritance and mutation ("biological evolution") lead to much the same dynamics. By studying these dynamics it is therefore possible to make contributions to a number of different disciplines simultaneously.

We have worked on deterministic as well as stochastic models. Stochastic models of evolution are also crucial for the theory of equilibrium selection in games. There is thus a close link between Projects 1.1 and 1.2.

Models of evolution are typically constructed by postulating particular stochastic hypotheses at the individual level, and then studying the population dynamics to which these hypotheses give rise. Seymour and Vaughan have undertaken several investigations the purpose of which was to understand better the link between individual dynamics and aggregate population dynamics and to derive predictions regarding the aggregate dynamics.

Vaughan (1996) has considered the microfoundations of aggregate evolutionary dynamics. A number of papers in the recent literature have focused on behaviour at the population level, i.e., in which the evolution of the total numbers in the population following certain courses of action are analysed. Vaughan has peered underneath the macro level, and considered how individual agents make their decisions. The aim was to investigate the nature of the aggregate evolutionary equations implied by the dynamical equations of the individual agents in the context of a population in which an individual agent may interact with either a subset, or the entirety of the population.

The analysis focused on the behaviour of individual agents in terms of their strategy choice, and derived the micro-configuration of choices by agents. Subsequently the aggregate evolutionary equations specifying the dynamics of the proportion of the population playing different strategies was derived. These equations show that the population may settle down into a state in which the aggregate number taking particular courses of action appear stable, although individual agents may or may not settle down to stable choice of actions over time.

In ongoing work, Seymour and Vaughan consider a large, heterogeneous population of agents, in which each agent is programmed with a particular type-characterising 'attribute'. At multiples of a small time interval τ two agents are chosen at random (without replacement) from the population, and with some probability they play either a 'birth' game, a 'death' game or a 'redistribution' (or mutation) game, or some (probabilistic) mixture of these. The possible outcomes of a birth game add agents to the population, those of a death game remove one or both of the players, and the outcomes of a redistribution game redistribute attributes amongst the population. Actual outcomes are determined probabilistically by the players' current attributes. Most models developed in biological and social-learning contexts can be construed as specialisations of this general scheme. In the limit of continuous time ($\tau \rightarrow 0$), dynamic models, both deterministic (generalised replicator dynamics) and probabilistic (Kolmogorov-type equations) are obtained in three distinct model scenarios. The two key parameters, hypotheses about which determine these scenarios, are the probability per time step with which a game is played, and a small parameter η which links the 'rate of activity' (the probability with which an individual is called on to interact - always assumed finite) to population number (which becomes infinite in the limit $\eta \rightarrow 0$). Two of the three models produce the same continuous-time limiting dynamics, with stochasticity disappearing as the population becomes infinite. Equations determining first order corrections for a finite population are also obtained. However, the third model produces a diffusion process even in the infinite-population limit. This residual stochasticity is determined by correlations at the population level between possible game outcomes. It is planned to develop this theory further by investigating possible equilibria of these systems.

In related work, Matros (2002) has modelled an evolutionary process with multiple decision rules. For finite n-player games he has proved that if every individual has a set of rules, which contains an imitation rule, the best reply rule, and possibly other higher degree best replies, then the long run predicted outcome is the same minimal curb configurations as obtained for Young's (1998) adaptive learning process when the error rate is zero. In a special class of games the efficient outcomes are selected. However, minimal curb configurations can be chosen other than those given in Young's (1998) book, when the error rate approaches zero through non-zero values.

Several pieces of work have tackled the case in which evolution selects among an infinity of strategies. One simple case is when the underlying game is finite, but players can choose so-called mixed strategies, i.e. strategies that randomise over the set of pure strategies. Reinhard Selten proved that mixed strategies cannot be evolutionarily stable in asymmetric games. However, his fellow Nobel prize-winner Harsanyi has a result that biologists have interpreted to mean that mixed strategies are always evolutionarily stable if properly interpreted. Binmore and Samuelson (2001a, b) have tried to resolve this issue. They argue that part of the problem is a confusion

about the meaning of “asymmetric” in Selten’s result. But a paradox remains even when this issue is resolved. Binmore and Samuelson have shown that the question of whether a mixed strategy is evolutionarily stable depends on the environment in which the game is played. If the available signals that tell an animal its role in a potentially asymmetric game are clear and cheap and the signals that tell it the game’s payoffs are ambiguous and expensive, then mixed equilibria will not survive long. But they may survive for very long periods at the other end of the range.

In a more comprehensive research effort, Seymour (2000) has developed a general theory of ‘Positive Definite-Adaptive’ (PDA) evolutionary dynamics for (asymmetric) games with continuous pure strategy sets which are subsets of some Euclidean space (e.g. the Ultimatum Game and the Nash Demand Game). Mixed strategies are then probability measures on the Borel subsets of these pure strategy spaces. For example, recent work of Schlag and Hofbauer (1998) on sequential imitation has shown the importance of generalisations of the replicator dynamics in asymmetric games which introduce multipliers into the standard linear form of these dynamics (i.e. obtained by applying a linear operator to the opponent’s strategy), rendering them non-linear in a particular way. Seymour’s theory can incorporate this type of dynamics in an infinite-dimensional context. Seymour showed that, under mild assumptions on the class of PDA dynamics, asymptotically stable dynamic equilibria are Nash equilibria satisfying certain strictness conditions, and that ‘strongly’ strict, pure-strategy Nash equilibria are strongly asymptotically stable (i.e. in the so-called ‘strong topology’ on the relevant measure space). This latter notion requires that an equilibrium response should not only be strictly better than any alternative, but that there should in fact be a finite advantage over any alternative strategy.

Dissemination: *Prominent publications* include: Binmore and Samuelson (*Games and Economic Behaviour* 2001a); Binmore and Samuelson (*Journal of Theoretical Biology* 2001b); Matros’, Seymour’s and Vaughan’s ELSE working papers; *Key presentation* include: Vaughan’s presentation “Evolutive Equilibrium Selection” at GAMES 2000, First World Congress of the Game Theory Society, Bilbao.

Project 1.3: Evolution and Bargaining

Aims and Objectives: This project aims to investigate issues specifically linked to bargaining by using an evolutionary approach. Without strong rationality assumptions, most bargaining situations have an indeterminate outcome, and the objective is to show how adaptive adjustment processes by bargaining agents can resolve this indeterminacy.

Researchers: Agastya (ELSE), Binmore (ELSE), Seymour (ELSE), Swierzbinski (ELSE), in collaboration with Gale, Piccione (LSE), Proulx (University of California at Santa Barbara), and Samuelson (Wisconsin).

Funding: ELSE’s core funding has supported Seymour and Swierzbinski’s research through teaching buyouts. The project has also received support from the Leverhulme Trust through Binmore’s funding as Leverhulme research professor.

Duration: 1995-2000

Results: The Ultimatum Game is said to embody the reasons why neoclassical economics is inadequate to describe how real people behave. A mythical philanthropist offers Adam and Eve a sum of money that they can keep if they can agree how it should be divided. The rules of the bargaining game require that Adam make a proposal to Eve on how the money should be split. Her role is restricted to accepting or refusing Adam's offer. If she refuses, the philanthropist takes his money back.

It is said that neoclassical economics requires that Adam should offer Eve only a penny and that she should accept. It is true that rational expectations theory predicts this outcome, but game theory says that any split of the money between Adam and Eve can be supported as a Nash equilibrium. In fact, experiment shows that Adam offers Eve something close to half the money and that if he offers her a third or less, there is an even chance that she will refuse his offer.

Binmore, in joint work with Larry Samuelson and John Gale (1995), has used computer simulations to study slightly perturbed versions of the replicator dynamics for the Ultimatum Game, and finds that these do not converge on the rational expectations outcome, but on a split of the money in which Eve receives a substantial share. They interpret this result as meaning that it is not necessary to invent exotic behavioural theories to explain the data from the Ultimatum Game, since the data is more readily explicable in terms of a norm adapted to repeated bargaining situations gradually adjusting to one of the Nash equilibria through a slow process of trial-and-error adjustment.

Whereas Binmore, Samuelson and Gale work with a simplified version of the Ultimatum Game in which only small number of offers is considered, Seymour (2000) has analysed a model for the original, infinite game. This requires the study of the infinite-dimensional replicator dynamics with mutational noise. The mutational noise represents the influence of behavioural dispositions derived from prior social experience in bargaining situations. Seymour finds that the subgame-perfect equilibrium is selected in the most naive low-noise limit. However, he also shows that the long run behaviour of the dynamics can settle on an equilibrium far from the subgame-perfect equilibrium when other limits involving the two noise parameters are taken, but with Adam never offering less than a quarter of the pie.

A more elaborate model of bargaining is Rubinstein's alternating offers model. In this model, as Rubinstein showed, with perfect information on each side, there is a unique subgame-perfect equilibrium. If this equilibrium is used to predict the bargaining outcome, then how much each bargainer will get is determined by their attitudes to risk and the rate at which they discount time.

Of course, in most real bargaining, lack of information about the circumstances of one's bargaining opponent is crucial and so Rubinstein's result is only the first signpost on a road along which we have not yet travelled very far. There are also doubts about the validity of the rational expectations assumptions built into the idea of a subgame-perfect equilibrium, as we saw when looking at the Ultimatum Game.

Binmore, in joint work with Michele Piccione and Larry Samuelson (1998), has shown that one does not need such strong assumptions as Rubinstein adopted to get results. Binmore and his co-authors first relax the assumption that the bargainers are perfectly rational by modelling them as computing machines. They then look for evolutionary stable machines on the assumption that, other things being equal, nature will prefer simpler machines to more complex ones. The conclusion is that the only outcomes in a Divide-the-Dollar Game that can survive are those between the Rubinstein solution and the fifty-fifty split. In the case in which the players are patient and discount time at the same rate, the authors then recover Rubinstein's uniqueness result without his strong rationality assumptions.

We have also undertaken experimental work that is aimed at testing evolutionary approaches to bargaining of the type described here. In joint work, Binmore and Swierzbinski, with Proulx (2001), have studied the prediction of Rubinstein's bargaining theory that a bargainer with a large outside option will get only negligibly more than his outside option after reaching a deal with his bargaining partner. Since he is then almost indifferent between agreeing and not agreeing to the deal, one should therefore expect to see a considerable amount of disagreement in this situation - which is exactly the situation contemplated in the well-known hold-up problem. The experiment generates results that accord well with the theory.

Seymour, in collaboration with his research student Prangle (partially ELSE-funded) has begun a study of the theoretical basis of Network Exchange Theory (NET). NET is a (partially) theoretical and experimental framework developed over the last decade or so by sociologists, with the aim of trying to understand how (socio-economic) agents respond to bargaining opportunities when they are embedded within a network of connections to other agents. In its simplest form, each agent is allowed to divide a fixed surplus with another agent to be chosen from the set of possible partners which the network structure makes available to him, provided he can obtain the agreement of such a partner, who herself faces the same problem. We are attempting a non-cooperative game-theoretic analysis of situations of this kind. The strategic thrust of this research is the attempt to understand the influence of one homogeneous social group on another through the medium of exchange, with respect to: (i) power relations in bargaining situations, (ii) learning and rational choice, (iii) socially-derived expectations, dispositions and norms. Some simple preliminary results are in place concerning networks with simple structure. We aim to apply adaptive learning models to investigate how agents can adjust to these complex situations. We have recently established contact with the group of sociologists at the University of Munich with a view to collaboration in this area.

In addition, Agastya has studied adaptive play in multiplayer bargaining situations. For a class of economies that can be expressed in terms of a real valued characteristic function, he first shows that all self-perpetuating allocations realized from a simple bargaining game must be core allocations although players make simultaneous demands for surplus and only on their own behalf. Following this, the author provides a sufficient condition under which the society eventually learns to divide the surplus according to some core allocation, regardless of the initial history.

Dissemination: *Prominent publications* include: Agastya (*Review of Economic Studies*, 1997), Gale, Binmore and Samuelson (*Games and Economic Behavior*,

1995); Seymour (*Journal of Mathematical Sociology*, 2000); Binmore, Piccione and Samuelson (*Journal of Economic Theory*, 1998); Binmore, Swierzbinski and Proulx (*Economic Journal*, 2001).

Project 1.4: Applications of the Mathematical Theory of Evolution

Aims and Objectives: Beyond the bargaining models analysed in the previous project we have also worked on some further applications of the mathematical theory of evolution. The goal of this work is to demonstrate the wide range of problems to which evolutionary methods can be applied. These have included the interaction between social class and bargaining, stratification processes which affect inequality, and an analysis of Rubinstein's "electronic mail game".

Researchers: Binmore (ELSE), Seymour (ELSE), Ponti (ELSE), Tröger (ELSE), Vaughan (ELSE), with Ania (Vienna), Wambach (Munich) and Samuelson (Wisconsin).

Funding: ELSE's core funding has supported Seymour and Vaughan's research through teaching buyouts. The project has also received support from the Leverhulme Trust through Binmore's funding as Leverhulme research professor. Ponti received support from a scholarship funded by the European Union.

Duration: 1995-2001

Results: Tröger (2002) has used an evolutionary approach to demonstrate that sunk costs matter for bargaining outcomes: the set of long run outcomes depends on the investment cost function, and the efficient incentives provided. Adding the investment decision to Young's evolutionary bargaining model yields a long-run outcome in which efficient investment prevails and the investor's share of the pie approximates the maximum of (i) the smallest share that induces efficient investment, even if the investor expects to appropriate the available pie from every inefficient investment, and (ii) half of the pie.

Tröger, with Ania and Wambach (forthcoming) has also re-examined the equilibrium non-existence problem in Rothschild and Stiglitz' insurance market. Firms are boundedly rational and offer menus of insurance contracts that are periodically revised (profitable competitors' contracts are imitated and loss-making contracts are withdrawn). Firms occasionally experiment by random withdrawals and/or innovations to contracts, and consumers buy the best contract on offer. It is shown that Rothschild and Stiglitz' candidate competitive equilibrium set is the unique long-run market outcome provided innovation experiments are not too radical.

Ponti and Seymour have studied the interaction between social class and bargaining. They investigate the evolution of a population whose members use their social class to coordinate their actions in a simple tacit bargaining game (Chicken). Ponti and Seymour interpret the equilibrium behaviours that the players may adopt as a function of their class, as 'customs' (or 'conventions'). Players may change their class depending on the outcome of the game, and may also change their custom as a result

of some learning process. Ponti and Seymour consider a learning process that has both a component which responds directly to a breakdown in coordination (due to a mismatch of customs) and an aspirational component, which models an agent's ambition to attain a higher reward within the class structure. They find that, although any custom (when it operates alone within society) generates the same limiting class distribution as any other, these limiting distributions can be ranked according to their between-class 'mobility'. When players are allowed to change their custom, then customs which promote greater social mobility predominate in the long run, even though no one custom is selected.

In separate work, Ponti and Seymour have studied stratification processes, i.e. processes which generate inequality in society. They examine the evolution of a population whose members compare their relative income to coordinate actions in a simple bargaining game (the Nash Demand Game). Social position depends not only on an objective measure (say income), but also on individual judgement, and agents in the model society employ both features in determining which equilibrium to play. First, each new bid reflects the relative current position of the players, as they perceive it. Second, a subjective element is introduced, in that players can decide how large their difference in current income has to be before they regard it as 'significant' for the new bid. That is, agents have a variable subjective threshold. If the income difference is below this threshold, a player will demand half the pie; if above it, she will bid proportionately to the perceived income difference. The model yields the following conclusions. If individuals form fixed, unambiguous images of their position in the social structure (i.e. a uniform subjective threshold for all agents), then social inequality will eventually disappear, and the income stream of each agent converges to a uniform level. On the other hand, if social images vary between individuals, and are free to evolve through some learning process, then inequality persists, with society divided largely into the very rich, the very poor and a (large) middle class. Furthermore, 'class consciousness' (i.e., narrower subjective thresholds) is more pronounced at the two income extremes of the social ranking.

Binmore, in joint work with Larry Samuelson (2001), has revisited a model of Rubinstein in which one player is informed that the game he plays with another player has changed and so they would both profit from switching strategies. The player sends a message to the other player to this effect, but there is a small probability that any such message is not received. The other player therefore transmits a confirmation of receipt, whose receipt the first player confirms in turn. Such an exchange of messages continues until it is eventually brought to a halt by a transmission failure. Rubinstein's analysis of this game, which is known as the "electronic mail game", has shown that rational coordinated action is impossible in his model. However, Binmore and Samuelson's work shows that Rubinstein's conclusion depends on making unrealistically strong assumptions. If, instead, replying is voluntary and involves small costs, then there are equilibria in which rational coordination takes place after a suitably large number of exchanges of messages. Binmore and Samuelson then ask which of the large number of equilibria can be thrown out on the grounds that they are not evolutionarily stable. The only equilibrium that fails to be evolutionarily stable is the equilibrium in which there is no rational coordination.

Vaughan has investigated equilibrium selection in neoclassical and other models of economic growth. Recent work on comparative patterns of economic growth and

development has emphasised the possibility of the existence of multiple equilibria. Empirical evidence may also suggest the existence of such equilibria. The emergence of models that have such a structure raises the question of the equilibrium to which economies converge. Thus we have the development of theories related to so-called global, conditional and club convergence. In deterministic models the equilibrium selection appears reasonably straightforward; different initial conditions lying in different “basins of attractions” will converge to different equilibria. Equilibrium selection will depend on the set of initial conditions. However, in the case in which the development of the economies are not solely determined by initial conditions, but may also be influenced by stochastic events, then convergence to the equilibrium determined by presence within a particular “basin of attraction” may not occur. In general we will find economies wandering in and out of different basins dependent on the influence of the stochastic shocks affecting the economy. The approach adopted by Vaughan draws heavily on the recent literature on equilibrium selection processes in evolutionary game theory.

Dissemination: *Prominent publications* include: Tröger (*Journal of Economic Theory*, 2002); Tröger, Ania and Wambach (*Games and Economic Behavior*, forthcoming); Ponti and Seymour (*ELSE Working Paper*, 1997); Binmore and Samuelson (*Games and Economic Behaviour*, 2001); Vaughan (*ELSE Working Paper*, 1996).

Project 1.5: Evolution, Mate Choice and Parental Investment

Aims and Objectives: This project aims to investigate some of the aspects of human behaviour that might be directly influenced by our common biological evolutionary heritage. The delineation of such deep dispositional constraints on human behaviours could have significant implications for the understanding of contemporary psychological, sociological and economic issues.

Researchers: Dunbar (ELSE), Plotkin (ELSE), Lycett (ELSE), Miller (ELSE), Seymour (ELSE), Sozou (ELSE), in collaboration with Bereczkei (Pecx), Pawlowski (Wroclaw), Volland (Giessen),

Funding: Dunbar, Plotkin, Seymour and Sozou received support from the ELSE Core grant. Miller received funding as an ELSE senior research fellow.

Duration: 1995 - 2005

Results: The principal focus of Dunbar’s research with respect to mate choice has been on exploring the conflicts and compromises that arise when an individual is forced to operate within a biological market where the objects of its interest (i.e. prospective mates) also have preferences (and may have stronger bargaining hands). Much of this work has been based on the quantitative analysis of personal advertisements, though some questionnaire and observational studies have also been undertaken. Since mate choice is a form of social negotiation within a constrained market, we can view advertisements as opening bids in a game where only very general information is available. This has allowed us to explore the social,

demographic and economic contingencies that force individuals to compromise on their ideals. Dunbar and his collaborators have been able to show (a) that human mate choice preferences can be understood in terms of relatively simple evolutionary principles, (b) that individuals are very sensitive both to their own bidding hand and to the demands of the market, (c) that they exploit quite subtle forms of deception in order to make higher demands than they would otherwise be able to do, and (d) that these strategies are strongly age- and sex-dependent. This work involved collaboration with Dr B. Pawlowski of the University of Wroclaw (Poland).

The second area of focus in this project has been on parental investment strategies. This has involved two major ongoing collaborative projects by Dunbar. One (with Bereczkei of the Medical University of Pecs, Hungary) has focussed on sex-biased patterns of parental investment among Hungarian Gypsies. Dunbar and Bereczkei have been able to explain the unusual (and very striking) female bias in Gypsy birth sex ratios (and parental investment patterns right the way through to the end of childhood) in terms of parents' attempts to manage the reproductive potential of their children in order to maximise their own fitnesses. Remarkably, we have been able to show a quantitative fit between sex-biased investment patterns and the ratio of fitness payoffs (measured in terms of numbers of grandchildren) between the two sexes of offspring. This study is unique in being able to close the evolutionary loop by demonstrating that fitness consequences map directly onto (and thus apparently guide) behavioural decisions in humans.

Dunbar's second study in this area has involved collaboration with Voland (Giessen University, Germany) and Lycett (Liverpool) and exploits opportunities for measuring behavioural outcomes provided by a very large historical demographic database (containing vital and social data on the members of some 16,000 families from a cluster of parishes in North West Germany over a 150-year period). This research has again focussed on sex-biased patterns of parental investment (which Voland and Dunbar had previously shown to be contingent on economic factors associated with population growth). Dunbar, Voland and Lycett's principal aim in this project has been to determine whether or not investment decisions in the two sexes (as indexed by differential mortality) genuinely have the fitness payoffs that would be expected if parents really were trying to manage their own fitness. By tracing the demographic consequences of parental preferences for the two sexes of offspring, they have been able to show that parents seek to manipulate investment in offspring in such a way as to maximize lineage survival.

Dunbar and Plotkin have undertaken experimental studies of kin selection and altruistic behaviour. This work investigates the validity of 'Hamilton's rule' in humans, and concerns the extent to which altruistic behaviour is partly caused by degree of genetic relatedness. Dunbar and Plotkin have carried out experimental cross-cultural studies both in the UK and South Africa. Results are still being collated and assessed.

Seymour and Sozou have studied theoretically the role of gift giving in human and animal courtship. Such gifts tend to be "expensive", i.e. costly to the giver but of low intrinsic value to the receiver. Seymour and Sozou propose an evolutionary explanation, modelling courtship as an asymmetric game between the sexes. The game involves a single gift being offered by the male, followed by the female

choosing whether to accept or reject the gift, and then whether or not to mate. Acceptance of a gift eliminates the female's uncertainty about the type of gift offered, but incurs a small fitness cost. If mating occurs the male then chooses whether to desert or to help care for the young. Seymour and Sozou find evolutionary equilibria in which gifts of value to the female are never offered, even to attractive females, though gifts that are offered are costly to the male ("expensive"). Indeed, the offer of an (apparently) valuable gift will be rejected. Other equilibria exist in which only valuable gifts, or a mixture of valuable and expensive gifts are offered to attractive females. The results of this research show that the cost of gifts may function as an indicator to the female of her attractiveness to the male, and hence of his intention to help care for the young. At the same time, a gift with low intrinsic value means that there is no incentive for females to act as "gold-diggers" and accept gifts from males with whom they have no intention of mating. Hence the economic inefficiency of courtship gifts facilitates the matching of mutually attractive partners.

Seymour has modelled a two-sex society in which evolving social signals are used in male-male and female-male interactions (modelled as competitive and coordination games, respectively). Pre-play signals are used to indicate the likelihood that potential players will play one of two possible strategies (Hawk of Dove) in either of the two types of game. Outcomes from one type of game can influence behaviour in either game type. The manner in which participants modify their behaviour in the light of experience is modelled by endowing agents with certain signal-dependent behavioural dispositions. The evolutionary model used is derived from the class of models developed by Seymour in related projects (Project 1.2). The thrust of this work is to analyse the ways in which female-male interactions can modulate the effects of male-male interactions to produce signal diversity within a society.

Miller's major book *The Mating Mind* on evolutionary psychology has been written and published within the duration of this project. Miller explores the extent to which courtship and sex have been instrumental in shaping the human mind over our evolutionary history. He argues that much of the subtlety of modern human psychology, in particular the capacity to reason, should be attributed to runaway sexual selection of the kind that created the peacock's tail and the elk's antlers.

Dissemination: *Prominent publications* include: Dunbar and Pawlowski (*Proceedings of the Royal Society of London*, 1999); Dunbar, Lycett and Voland (*Proceedings of the Royal Society of London*, 2000); Bereczkei and Dunbar (*Proceedings of the Royal Society of London*, 1997); Seymour and Sozou (*ELSE Working Paper*, 2001); Miller (*Demos Quarterly*, 1996); Miller (*The Mating Mind*, 2000). *Key presentations* include numerous seminar presentations by Dunbar and Plotkin.

Project 1.6: Group Size, Social Cognition and Evolution

Aims and Objectives: Behavioural decision-making is constrained by social group size, brain size and cognitive mechanisms. This project investigates variables affecting group size in primates (including humans), and seeks to identify systematic relationships between group size, brain size and cognitive function.

Researchers: Dunbar (ELSE) and Heyes (ELSE), in collaboration with Barrett (Liverpool), Bentall (Manchester), Call (Max Planck Institute, Leipzig), Huber (Vienna), Kinderman (Liverpool)

Funding: Dunbar and Heyes received support from the ELSE Core grant. The project has also been supported by grants to Dunbar from Hewlett-Packard and the University of Liverpool Development Fund.

Duration: 1995-2005

Results: Dunbar has developed a set of four taxon-specific system models of socioecology from the wealth of data on the behaviour and ecology of individual groups of animals generated by his field studies and those of other primatologists. These models, which show how environmental and demographic variables impose limits on group size, are robust (despite the large number of system equations involved) and simple. Moreover, they predict with considerable precision the variation in group size within a taxon's geographical range, the habitat-specific size at which groups typically undergo fission and the likely reason why populations go extinct in particular habitats. The current objective is to weld these taxon-specific models together to create a general model of primate sociality.

Dunbar's evidence of a direct correlation between group size in primates and relative size of the neocortex is now an object of consensus in a controversial field. Investigating the reasons why this relationship holds, he has conducted two major empirical projects on social cognition. The first, conducted in collaboration with Louise Barrett (Liverpool) and Josep Call (Max Planck Institute, Leipzig), included studies of mental rehearsal, causal inference and theory of mind in captive and semi-wild great apes and macaques, and of theory of mind in dolphins. The second, with Bentall (Manchester) and Kinderman (Liverpool), is studying advanced theory of mind (up to fifth-order intentionality) in healthy adults and paranoid schizophrenics, and is planned to include the use of fMRI to investigate the neurobiology of social cognition. The results of these studies to date suggest that key differences in social cognition between human and nonhuman primates lie in 1) the extent to which the organism can engage in parallel processing of basic causal and observational information about the world, and 2) the virtual time depth over which such processing can be carried out (via, for example, mental rehearsal).

Heyes work on social cognition in primates has focussed on theory of mind and self-recognition. Her analysis of the entire body of empirical work in these fields has identified key conceptual weaknesses and methodological problems. Building on this, she has formulated a new, nonverbal test of theory of mind, involving conditional discrimination training and transfer tests, which has been used with both children and chimpanzees.

Dissemination: *Prominent publications* include: Dunbar (*Proceedings of the British Academy*, 1996); Dunbar (*Nature*, 1997); Heyes (*Behavioral and Brain Sciences*, 1998). *Key presentations* include: Dunbar's (1996) plenary lecture to the International Society for Human Ethology, and Heyes' (1997) plenary lecture to the International Ethological Congress.

Project 1.7: Evolution, Altruism, and the Social Contract

Aims and Objectives: The aim it is to use game theory to model social contracts and to create a naturalistic theory of ethics.

Researchers: Binmore (ELSE).

Funding: The project received support from the Leverhulme Trust through Binmore's funding as Leverhulme research professor.

Duration: 1995-2002

Results: Binmore has been engaged in a wide-ranging project whose aim it is to use game theory to model social contracts and to create a naturalistic theory of ethics. His work replaces the Kantian foundations for the moral theories of Harsanyi and Rawls by assumptions that can be defended on biological grounds. In particular, an evolutionary defence is offered of the Rawlsian original position. A theory of interpersonal comparison of utility is proposed that fills a gap in Harsanyi's approach. At the same time, Harsanyi's commitment assumptions are abandoned, with the result that one obtains a naturalistic defence of Rawls' "difference principle" that is acceptable to economic theorists.

Dissemination: Binmore's book *Playing Fair: Game Theory and the Social Contract* was written before ELSE began, but a second volume, *Just Playing: Game Theory and the Social Contract II* (Binmore, 1998) was written while Binmore was ELSE director. This book presents his social contract theory in more detail. Binmore has also written a long sequence of papers that present shorter versions of his theory for a variety of audiences.

Project 1.8: Evolution of Cognition

Aims and Objectives: This project challenges the view that an evolutionary psychology of cognition is necessarily nativist.

Researchers: Heyes (ELSE), Huber (Vienna)

Funding: The Konrad Lorenz Institute provided comprehensive funding for an international conference on the topic of the project organised by Heyes.

Duration: 1995-2002

Results: Heyes has developed a model distinguishing four routes of cognitive evolution: phylogenetic construction, in which natural selection shapes a cognitive mechanism; phylogenetic inflection, where natural selection diverts the input to a cognitive process without altering its mechanism; ontogenetic construction, in which developmental selection shapes a cognitive mechanism; and ontogenetic inflection,

where developmental selection diverts input but does not alter mechanism. This model, which identifies evolutionary processes as those that operate according to a variation-and-selective-retentional algorithm, has been tested against data bases on language, imprinting, spatial memory, imitation, face processing and theory of mind. The results support a nativist/phylogenetic construction account of cognitive evolution only in the case of language. The evidence suggests that imprinting and spatial memory are products of phylogenetic inflection, that face processing and theory of mind have evolved through ontogenetic construction, and that the capacity for imitation learning results from ontogenetic inflection. The latter result is of particular interest. It implies that, in so far as social evolution is mediated by imitation, it is not tethered to inclusive fitness by reliance on a dedicated, innate cognitive module.

Dissemination: *Prominent publications* include books by Heyes and Huber (2001) and Heyes and Hull (2001). *Key presentations* were made at an international meeting on the evolution of cognition organised by Heyes and Huber in 1998.

2. Learning Approaches

Project 2.1: The Theory of Learning in Repeated Decisions Problems and Games

Aims and Objectives: Research in this project is concerned with the learning behaviour of individuals in repeated decision problems or games. The focus is on the case in which either the same decision problem is experienced many times by the same agent, or the same game is played repeatedly by the same agent, with no strategic connection between the repetitions.

Researchers: Börgers (ELSE), in collaboration with Sarin (Texas A&M University) and Morales (Malaga).

Funding: ELSE's core funding has supported Börgers' research through teaching buyouts.

Duration: 1995 - 2005

Results: Börgers, in joint work with Rajiv Sarin from Texas A&M University, has explored the theory of reinforcement learning in decisions and games (*Journal of Economic Theory*, 1997). This research describes the learning behaviour of agents who do not have much prior knowledge of the environment about which they are learning, and who are relatively unsophisticated in their information processing. Agents' behaviour is captured by stochastic models that describe how experiences change the agents' likelihood of choosing one action rather than another. The models are rooted in the tradition of mathematical learning theory in psychology.

Börgers and Sarin focused initially on a particularly simple specification of reinforcement learning due to Cross. They explored the relation between Cross' learning model and the replicator dynamics of evolutionary game theory. They showed how reinforcement learning models form a bridge between learning theory and evolutionary theory. At a methodological level, this work also contributed to the study of the relations between stochastic dynamic models in discrete time and deterministic dynamic models in continuous time.

In later work, Börgers and Sarin have extended their research to incorporate aspiration levels into reinforcement learning. They showed that in this case reinforcement learning models predict some degree of "probability matching", a form of irrationality that has also been studied in the psychological literature on learning.

Börgers and Sarin, in joint work with Morales, have introduced an axiomatic approach to reinforcement learning. They show that all reinforcement learning models with certain properties are closely related to evolutionary models.

Dissemination: *Prominent publications* include: Börgers and Sarin (*Journal of Economic Theory* 1997, *International Economic Review* 2000); *Key presentations* include Börgers' MIT/Harvard seminar.

Project 2.2: Experimental Investigations of Learning in Repeated Decision Problems and Games

Aims and Objectives: A number of repeated decision problems yield results that conflict with rational norms. This project sought to reconcile these phenomena with rational decision theory by examining the roles of incentives, prior knowledge and feedback.

Researchers: Börgers (ELSE), Huck (ELSE), McCarthy (ELSE), Shanks (ELSE), Tunney (ELSE).

Funding: ELSE's core funding has supported Börgers, Huck and Shanks through teaching buyouts, and McCarthy and Tunney through postdoctoral appointments. The work was also supported by an ESRC project grant to Shanks.

Duration: 1996-2005

Results: This project examines experimental evidence related to the theories developed in Project 1. In a series of experiments by Shanks and Tunney participants were asked to make repeated choices between two options. A monetary payoff of fixed magnitude is given with probability $p = .7$ for one choice, and $p = .3$ for the other. Probability matching refers to behaviour in which participants match their response probabilities to the payoff probabilities and so do not maximise the overall (expected) payoff. As mentioned in the description of Project 2.1 some theories of reinforcement learning predict probability matching. Probability matching is an irrationality because the overall (expected) payoff of the agent is maximised when participants allocate all of their responses to the option that has the highest probability of returning a payoff.

Shanks and Tunney's results show that sufficiently large financial incentives and regular feedback greatly reduce the extent of sub-optimal behaviour in repeated decision problems. The rate at which people learn to allocate all of their responses to the high probability alternative has been greatly increased in Shanks and Tunney's experiments in comparison to previous experiments.

In related work on one-person decision problems with more than two choices (multi-armed bandits), Börgers and Huck have begun to study systematically the effect of prior information and feedback information on choice behaviour and learning. First results indicate that the impact of information on choice depends on the complexity of the decision problem.

Dissemination: *Prominent publications* include: Shanks, Tunney and McCarthy (*Journal of Behavioral Decision Making*, 2002); Lagnado and Shanks (*Cognition*, 2002).

Project 2.3: Mathematical Models of Learning in Dynamic Decision Problems and Games

Aims and Objectives: This project concerns learning in dynamic and repeated games. This includes reinforcement learning, the effect of limited foresight in repeated games and 'learning by analogy'. The goal is to model situations in which players have limited foresight.

Researchers: Jehiel (ELSE).

Funding: ELSE's core funding has supported Jehiel's research through teaching buyouts.

Duration: 1995 -2002

Results: Jehiel and Samet (2000) have extended models of reinforcement learning to dynamic games of perfect information. They postulate that moves rather than strategies are being reinforced. Based on this assumption, they show that in the long run players will converge to the play of subgame perfect Nash equilibria.

Another form of dynamic strategic interaction is considered by Jehiel who has developed a theory of learning in repeated games. Here, unlike in Project 2.1, there is a strategic connection between different repetitions of the game. Jehiel's goal is to model players who have limited foresight. The concepts developed by Jehiel assume that forecasts are correct and rolling (with a constant horizon of foresight). Players take as their criterion the discounted sum of payoffs over their horizon of foresight, while in later work (2001), Jehiel assumes there is extra noise in the criterion that represents how players assess payoffs beyond their horizon of foresight. Jehiel (1998) proposes a learning model to justify the correctness assumption of the limited forecasts. Applied to the repeated prisoners' dilemma the approach (with noise) shows that it may be easier to sustain cooperation than to sustain defection when players have intermediate horizon of foresight.

Another issue with which Jehiel has been concerned is the issue of learning by analogy. In this work, 'learning by analogy' means that players group different contingencies, and use observations made in one contingency to forecast events in all contingencies in the same group. In ongoing research, Jehiel ("Analogy Based Expectation Equilibrium", 2001) proposes a framework to describe such situations: players play best-replies to their analogy-based expectations, and expectations correctly represent average behaviour in every analogy class (where the weight given to the various elements of the class itself depends on their frequency of visits). The approach is applied to finitely repeated prisoner's dilemma to show that cooperation in the early phase of the game followed by an end opportunistic behaviour may emerge for some categorizations of histories.

Dissemination: *Prominent publications* include: Jehiel (*Games and Economic Behavior* 1998, *Review of Economic Studies* 2001). *Prominent presentations* include a large number of presentations of this research by Jehiel in the United States including MIT-Harvard, Princeton, UPenn, Yale, and NYU. *Selected working papers:* Jehiel and

Samet (Learning to Play Games in Extensive Form by Valuation, 2000), Jehiel (Analogy Based Expectation Equilibrium, 2001).

Project 2.4: Empirical Evidence of Learning in Dynamic Decision Problems and Games

Aims and Objectives: To determine the basis of an apparent anomaly in rational decision theory, namely, melioration. To study Jehiel's theory of learning by analogy in experiments.

Researchers: Huck (ELSE), Jehiel (ELSE), Shanks (ELSE), Tunney (ELSE).

Funding: ELSE's core funding has supported Huck, Jehiel, and Shanks through teaching buyout and Tunney through a postdoctoral appointment.

Duration: 1996-2004

Results: In a series of experiments Shanks and Tunney have examined how people allocate choices between two alternatives when either the probability or magnitude of payoff varies as a function of the allocation of recent choices. On any one trial, option A had a higher immediate (probability or magnitude) payoff than B but, because the payoff on both options increased as a function of the number of responses allocated to B, and decreased with A, option B returned the higher overall payoff. In order to maximise their overall payoff participants should eventually allocate all of their responses to option B, but it is commonly observed that participants tend to prefer the option with the higher immediate payoff (A) irrespective of the consequences for their overall payoff. People readily learn to maximise their overall payoffs when the magnitude of each individual payoff is contingent upon their behaviour, but have more difficulty when their allocation of choices affects the probability of receiving a payoff. Counterintuitively, people are better able to learn about the relationship between their choices and payoff probabilities when they are allowed short periods to explore different strategies without any financial incentives. In this situation learning can be more efficient when it is not reinforced.

In further experimental work, Huck and Jehiel have begun to explore Jehiel's theory of analogy based equilibrium, as described in Section 2.3. First results indicate the importance of feedback information on the way player reasons. Huck and Jehiel will collect more data in the coming autumn.

Dissemination: Tunney and Shanks (*Journal of Behavioral Decision Making* 2002).

Project 2.5: Learning with Minimal Information in Games

Aims and objectives: To study what outcomes are achieved in games with ordered strategy sets when agents learn by (local) trial and error.

Researchers: Huck (ELSE) together with Normann (Royal Holloway) and Oechssler (Bonn).

Funding: ELSE core funding via Huck's teaching buyout.

Duration: 2001 - 2004

Results: This project studies the implications of a very simple learning process that can be applied whenever strategies are ordered (as quantities, prices, etc.) and agents have very little information about the game they are playing or are, in fact, even unaware of the fact that they are playing a game. Agents simply adjust their choice in one direction as long as this increases their payoff. Surprisingly, Huck, Normann, and Oechssler (2002) have shown that this yields collusive outcomes in finite dilemma games where agents move on a grid. This result has some appeal as it offers a completely new justification for cooperation among agents with very limited cognitive capabilities. Huck and co-authors have obtained a similar result for continuous Cournot games where the learning dynamics are modelled with differential inclusions. Currently, they try to extend their results to broader classes of games.

Dissemination: Huck, Normann, and Oechssler (*Journal of Theoretical Biology* 2002).

Project 2.6: Learning about Causation

Aims and Objectives: This project aims to understand a particular high-level cognitive judgement tasks – causal induction – from the perspective of a rational analysis.

Researchers: Shanks (ELSE), Lober (Marburg), Lopez (Malaga), Collins (Psychology, UCL)

Funding: ELSE's core funding supported Shanks via teach buyouts. The work has also been supported by a BBSRC project grant.

Duration: 1995-2003

Results: This project shows how complex cognitive judgments relating to causation may be grounded in simple reinforcement learning mechanisms. Key issues to date have been the contrast between momentary and integrative judgment strategies and the search for an adequate algorithm to capture causal judgments. The project bridges the gap between elementary learning and higher-level cognition.

Dissemination: *Prominent publications* include: Lober and Shanks (*Psychological Review* 2000). *Key presentations* include: Shanks (1999) to the Eastern Psychological Association, USA.

Project 2.7: Learning Through Imitation

Aims and Objectives: Whereas the projects described so far investigate how individuals learn from their own experience, we have also undertaken a major project concerned with imitation. Its aims are to elucidate, through theoretical and experimental work, the role of imitation learning in social evolution, and the cognitive mechanisms mediating imitation in human and nonhuman animals.

Researchers: Heyes (ELSE), Ray (ELSE)

Funding: ELSE's core funding has provided support for ad hoc research assistance, equipment and subject payments, and via Ray's postdoctoral appointment. The work has also been supported by BBSRC project grants to Heyes.

Duration: 1995-2005

Results: Heyes and Ray's theoretical work has focussed on the correspondence problem; the question of how an imitator is able to copy observed actions when sensory input during observation and sensory feedback from execution are in discrepant modalities or perceptual frames. They have developed an Associative Sequence Learning (ASL) model which offers a solution to the correspondence problem, and proposes that the cognitive mechanisms mediating imitation learning arise through ontogenetic inflection of task- and taxon-general processes; that they are not provided by an 'innate module'. One implication of this model is that cultural artefacts and practices contribute to development of the capacity for imitation, but that this capacity makes a distinctive contribution to social evolution only when it is combined with higher-order intentionality. Adopted by researchers in AI, the ASL model has been successfully implemented in robotic and connectionist systems.

Predictions of the ASL model have been tested in experiments with animals and humans. In the former, Heyes has developed a 'two-action' procedure that is now used by psychologists as the standard method of testing for imitation in animals. This work has also shown that birds are capable of motor, as well as vocal imitation, and that they will copy TFT video as well as live models.

Studies with adult human participants have demonstrated that imitative action is constrained by the same principles of stimulus-response compatibility as non-imitative action, and that imitation learning can be effector-specific. For example, in a serial reaction time task, participants who have learned a complex sequence of finger movements by imitation can use their sequence knowledge when the stimulus array is changed, but not when they are required to use their thumbs rather than their fingers to depress the keys. This is consistent with the ASL model and not with the view that symbolic mediation is an intrinsic part of imitation learning.

Dissemination: *Prominent publications* include: Heyes and Ray (*Advances in the Study of Behavior* 2000); Heyes (*Trends in Cognitive Sciences* 2001). *Key presentations* include: Heyes (1999) plenary lecture to International Ethological Congress.

3. Behavioral Economics

The Behavioral Economics research division is a recent addition to the ELSE centre and was created in 2001. This division has integrated some research projects that previously belonged to other divisions.

Project 3.1: Assessing and Forecasting the Effectiveness of Promotional Campaigns

Aims and Objectives: This project examines how well people can assess and use information about previous effects of promotional campaigns to predict effects of future ones.

Researchers: Harvey (ELSE). South (UCL).

Funding: ELSE contributed to Harvey's research expenses.

Duration: October 1998 - August 1999.

Results: The relation between promotions and their effects was varied (linear, exponential, damped, logistic, peaked). People's judgments revealed a strong tendency to linearise all these relations. This is consistent with earlier work on cue probability learning. Also, people were better able to interpolate within the range of promotions that they had previously experienced than to extrapolate outside that range. The project has demonstrated that simple rule-learning or exemplar-based models cannot account for these results.

Dissemination: This research was presented at: 17th Conference on Subjective Probability, Utility and Decision Making. Mannheim, 2000; 3rd International Conference on Memory, Valencia, 2001.

Project 3.2: Bounded Rationality: Theory and Evidence

Aims and Objectives: This project combines theoretical and empirical work in an examination of how normative decision-making strategies can be preserved under conditions, such as those promoting imperfect recall, which promote error.

Researchers: Börgers (ELSE), Heyes (ELSE), McCarthy (ELSE), Plotkin (ELSE), Newell (ELSE), Shanks (ELSE), Sozou (ELSE).

Funding: ELSE's core funding supports Börgers and Shanks through teaching buyouts, and experimental work through provision of equipment, subject payments, etc. This project has also been supported by a Leverhulme project grant to Shanks, and an ESRC postdoctoral fellowship to Newell.

Duration: 2001-2005

Results: We have begun a programme of theoretical as well as experimental work on bounded rationality. The theoretical work currently focuses on the optimal behaviour of agents with imperfect recall. Börgers has two ongoing projects in this area. One project investigates optimal learning by an agent with imperfect recall. The idea is that an agent with imperfect recall who acts in a changing environment will optimally pursue a programme of *random* experimentation. This is an interesting instance where randomised strategies are uniquely optimal. Moreover, the optimal behaviour rules resemble the stochastic learning rules for which the psychological literature on reinforcement learning provides evidence.

Börgers second project in this area studies the interaction among agents with imperfect recall. Börgers uses physical order as the metaphor for the shared memory of a society. Börgers shows that there are equilibria with the optimal amount of physical order as well as equilibria with too much, or too little order.

An experimental project by Heyes, McCarthy and Plotkin has examined how and why social interaction during recall of information leads to reduction in amount remembered and normalisation of content.

Experimental work by Newell and Shanks has been concerned with the suggestion made by Gigerenzer and Selten that people have access to a range of decision heuristics which achieve near-optimal outcomes without employing optimal decision algorithms. One such heuristic is Take-The-Best, which proposes that decisions between competing alternatives are based on single cues. If the cue with the highest validity discriminates between the alternatives, the heuristic proposes that a decision is made simply on the basis of this cue (i.e., this is a non-compensatory algorithm). If this cue does not discriminate, then the cue with the next highest validity is evaluated, and so on. Newell and Shanks are undertaking experimental evaluations of this and related heuristics in a range of choice situations with the goal of identifying the conditions under which people follow such strategies and those in which they adopt more normatively appropriate strategies. Thus far, the experimental work conducted demonstrates that heuristics thought to be highly robust and widely applicable to a range of decision-making environments are not as widely adopted as has been claimed by Gigerenzer.

In earlier theoretical research (that has been reclassified into this Research Division) Sozou has studied hyperbolic discounting in an environment with uncertain hazard rates.

Dissemination: *Prominent publications* include Sozou (*Proceedings of the Royal Society of London B* 1998), Newell and Shanks (*Journal of Experimental Psychology*, in press). *Key presentations* include: Newell and Shanks (2001) to the Society for Judgement and Decision Making, Florida.

Project 3.3: Inequity Aversion and Team Incentives

Aims and Objectives: To study the theoretical implications for incentive contracts of the supposed phenomenon of inequity aversion.

Researchers: Rey (ELSE).

Funding: Rey is occasionally hired as a research assistant by ELSE.

Duration: 2001-2003

Results: A number of recent papers have suggested that subjects in experiments exhibit inequity aversion: They dislike outcomes where they themselves are much worse off than other subjects, but they also avoid situations in which they themselves are much better off than others. This research project is interested in the implications of this observation for incentive contracts that an employer offers to his employees. We show that an employer can use inequity aversion among employees to his own advantage. In particular, he can offer relatively equitable outcomes in case the agents put in the desired effort, and he can threaten lazy agents with highly unequal outcomes. Rey's results complement other results in the literature that suggest that incentive contracts under inequity aversion lead to incomplete incentive contracts. This work was carried out by Rey, a PhD student of Börgers.

Dissemination: Rey's work has become an ELSE discussion paper in 2002.

Project 3.4: Intrinsic Work Motivation

Aims and Objectives: To investigate how, and under what circumstances explicit incentives can create perverse effort effects.

Researchers: Leaver (ELSE).

Funding: Funded out of ELSE's core grant by funding Leaver as a full-time researcher.

Duration: 2001 - 2003

Results: Over the last decade performance-related-pay has been introduced into a number of areas of the public sector (e.g. the Inland Revenue, NHS, schools). Public sector unions remain opposed to such schemes, claiming they de-motivate an already motivated workforce. This research aims to establish conditions under which explicit incentives can create perverse effort effects. Survey data suggests intrinsic rewards such as self-esteem / pride and external recognition play an important role in the public sector. Current work is focusing on the interaction between these motives and the informational content of extrinsic, performance-contingent rewards.

Dissemination: none yet.

Project 3.5: Behavioural Approaches to Environmental Decisions

Aims and Objectives: The exotic nature of many environmental resources provides a challenge for economists. Some of these goods involve very long time horizons, effects that span generations, or unusual risks, and hence raise issues such as the treatment of altruistic motives. The valuation of such goods therefore provides an opportunity both to test and to apply models of time preferences, preferences toward risk, and models of altruism.

Researchers: Swierzbinski (ELSE).

Funding: This project has received support from ELSE's core funding through Swierzbinski's teaching buyouts

Results: The valuation of environmental resources is a very important issue for policy makers. This valuation provides both a severe challenge and an opportunity for economists. For example, many important environmental resources are not bought and sold in markets. Such resources must be valued indirectly. One widely used method, contingent valuation, simply asks individuals to report their willingness to pay for an environmental improvement. Contingent valuation raises many questions at the boundary of psychology and economics that concern, for example, the nature and extent of biases in data obtained from such surveys. The findings from a series of questionnaires and surveys have identified differences in preference reversals reported in the first project by *Swierzbinski*, and variability in responses to versions of the same questionnaire type demonstrated in the second project.

Swierzbinski has two projects based on this idea. The first is based on a small contingent valuation survey conducted by Murato in the summer of 1996. That survey was designed to investigate the preferences of UK citizens for different management policies for the highly endangered black rhinoceros. As part of the survey, *Swierzbinski* and Murato included questions designed to discriminate between individuals whose time preferences could be described by the classical economic model with a constant discount rate and individuals with other sorts of time preferences. The time preferences for a large subset of survey respondents appear to be best described by something like a hyperbolic discount factor.

In a second project, *Swierzbinski* has investigated framing effects in contingent valuation. The double-bounded referendum format for contingent valuation randomly assigns respondents to versions of a questionnaire that differ in the size and order in which hypothetical payments for a public good are presented to respondents. Taking advantage of the controlled experiment which every such study comprises, *Swierzbinski* shows how simple comparisons of the summary results from each version of the questionnaire can be used to assess the extent to which the starting point and order in which payments are offered affect a respondent's reported willingness to pay. Using the famous Alaska -Exxon Valdez study as an example, these comparisons reveal large differences in the results from different versions of the questionnaire used in that study. The presence of such framing effects has important implications for environmental valuation.

Dissemination: The first project was presented to the 2001 summer meeting of the European Association of Environmental and Resource Economists. Papers are in preparation.

4. Mechanism Design

Project 4.1: Auctions With Externalities

Aims and Objectives: To make auction theory more applicable to real world settings by allowing for allocation externalities between bidders. The project will develop theoretical models to predict how bidders behave in the presence of externalities and will analyse auctions exhibiting certain desirable properties.

Researchers: Jehiel (ELSE) in collaboration with Caillaud (Paris), Compte (Paris), Moldovanu (Mannheim), Stacchetti (Michigan).

Funding: This project has received support from ELSE's core funding through Jehiel's teaching buy-out.

Duration: 1997 – 2002.

Results: Whenever bidders interact after an auction (e.g. competing for customers after license auctions) they are likely to care about the entire profile of allocations, not just their own allocation. This project explores the consequences of such allocation externalities.

In a series of papers Jehiel has shown that allocation externalities have a profound effect on equilibrium bidding behaviour. Jehiel and Moldovanu (2000) observe that entry fees and reserve prices in one-object auctions have different qualitative implications in the presence of externalities. Jehiel, Moldovanu, and Stacchetti (1999) characterise features of the optimal auction when bidders have private information, both on their valuation and on the externality they suffer when a competitor is allocated the good. Jehiel and Moldovanu (1999) analyse a complete information setting in which firms can resell the good and show that, while the good need not be allocated efficiently initially, it will eventually fall into the hands of the efficient agent. Caillaud and Jehiel (1998) show how the presence of externalities may make collusion among privately informed bidders more difficult.

In more recent work, Jehiel and Moldovanu (2001) analyse a mechanism design problem with interdependent valuations, multidimensional signals and various social alternatives, where agents possess private information that is relevant to other agents' valuations of every alternative. They show that, irrespective of the need for participation constraints, it is generically impossible to induce an efficient choice of alternative. This finding is in sharp contrast with well-known results in the private value case (e.g. Vickery, Clarke and Groves characterise mechanisms that deliver efficient social choices). An open task in this area is to determine the second-best mechanism.

Finally, Compte and Jehiel (2002) analyse the impact of the number of bidders on social efficiency. They show that, in the private value case and with second or ascending price auctions, increasing the number of bidders improves efficiency.

However, this ceases to be true in interdependent value contexts with asymmetric bidders.

Dissemination: *Prominent publications:* Compte and Jehiel (*Econometrica* 2002), Caillaud and Jehiel (*RAND Journal of Economics* 1998), Jehiel and Moldovanu (*Review of Economic Studies* 1999, *RAND Journal of Economics* 2000, *Econometrica* 2001), Jehiel, Moldovanu, and Stacchetti (*Journal of Economic Theory* 1999).

Project 4.2: Collusion in Auctions

Aims and Objectives: To investigate the vulnerability of auctions to collusion. The project will develop theoretical models that help to predict bidders' collusion in auctions and will investigate optimal policies for a seller in the presence of potential buyer collusion.

Researchers: Agastya (ELSE), Albano (ELSE), Larson (ELSE), in collaboration with Daripa (Birkbeck College), Germano (Pompeu Fabra, Barcelona) and Lovo (HEC, Paris).

Funding: This project has received support from ELSE's core funding through Agastya and Albano's teaching buy-outs and Larson's post-doctoral research position.

Duration: 1995 – 2003.

Results: This project has developed models of bidding rings where it is assumed that collusion can be enforced by some exogenous threat, as well as models where any collusive agreement must be self-enforcing (i.e. threats which enforce adherence to the collusive agreement occur within the auction game).

Agastya and Daripa (1998) investigate bidding rings and show that these need not lower the expected revenue of the seller. Thus, revenue maximising sellers may well have good reasons to allow bidding rings.

There has been substantial concern that in second price common value auctions groups of bidders will pool their information and submit a single joint bid in an attempt to reduce competition. Larson has explored the consequences of such joint ventures. In a common value setting, a group of bidders who pool their information suffer less from the winner's curse than they would have done if bidding individually. This effect encourages such groups to bid *more* aggressively. Larson identifies conditions under which the seller, nonetheless, does best to forbid group bids, and explores situations in which some group bidding might be optimal for the seller.

Albano, Germano and Lovo (2001) investigate the phenomenon of collusion in multi-object ascending auctions (e.g., the U.S. FCC auctions). They address the following question: Can we design simple auction mechanisms that guarantee the transparency of the bidding process, ensure information revelation and that are robust to (tacit) collusion?

Dissemination: *Publications:* Albano, Germano, and Lovo (*Economics Letters* 2001). *Working Papers:* Agastya and Daripa (1998), Collusion in Auctions.

Project 4.3: Multi-Unit Auctions

Aims and Objectives: To understand better the likely behaviour of bidders in a variety of multi-unit auction formats. The project will survey the relevant literature in a manner accessible to practitioners, and it will provide some extensions of existing theoretical results.

Researchers: Binmore (ELSE), Börgers (ELSE), Swierzbinski (ELSE).

Funding: The project has received support from ELSE's core funding through Börgers and Swierzbinski's teaching buy-outs. The project has also received support from the Leverhulme Trust through Binmore's funding as Leverhulme research professor.

Duration: 1997 – 2002.

Results: While undertaking advisory projects Binmore, Börgers and Swierzbinski have surveyed and evaluated the literature on multi-unit auctions. Two surveys have resulted from this research: Binmore and Swierzbinski (2000) and Börgers and Swierzbinski (2002). One of the main issues discussed in these papers is the comparison between uniform and discriminatory price auctions. Binmore and Swierzbinski emphasize the possibility of implicit collusion in uniform price auctions. Their paper illustrates this possibility by exhibiting equilibria of a complete information version of the auction game that had previously not been studied.

Dissemination: *Prominent publications:* Binmore and Swierzbinski (*Review of Economic Design* 2000). *Reports About Commissioned Research:* Börgers and Swierzbinski (2002).

Project 4.4: Further Issues in the Theory of Auctions

Aims and Objectives: To explore a variety of issues raised by our applied work in the area of auctions. The project will extend the existing theoretical foundations of auction advice.

Researchers: Albano (ELSE), Larson (ELSE), Matros (ELSE).

Funding: This project has received support from ELSE's core funding through Larson's and Matros' post-doctoral positions. The project will also benefit from Albano's teaching buyout in the year 2002-2003.

Duration: 2001– 2003.

Results: This project combines a variety of issues in the analysis of auctions.

Albano and Matros (2002) study the existence of mixed strategy equilibria in two classes of discontinuous two-player games with non-compact strategy sets. They obtain as a corollary of their main results a continuum of mixed strategy equilibria for the first and second price two-bidder auctions with toeholds under complete information.

The analysis of common value auctions is complicated by the fact that there are often multiple sets of equilibrium bidding strategies. Larson addresses this issue by developing a model in which bidders also have a small private value component for the object for sale and then deriving limiting equilibrium behaviour as private values vanish. He shows that, in certain cases, this approach can be used to select a unique equilibrium of the pure common value model. When bidders are asymmetric the relative “aggressiveness” of each bidder depends on their information about the common value, but also on how much information its bid provides to the other bidders about the common value (which depends on the private value component). Parametric examples are used to demonstrate how outcomes can vary sensitively (but intuitively) as the composition of private value and common value information held by the bidders changes.

Dissemination: *Working papers:* Albano and Matros (2002), Existence of Mixed Strategy Equilibria in a Class of Discontinuous Games with Unbounded Strategy Sets.

Project 4.5: Empirical Analysis of Spectrum Auctions

Aims and Objectives: To provide empirical foundations for future real world auction advice. The project seeks to understand bidding behaviour in recent real world spectrum auctions.

Researchers: Binmore (ELSE) with Klemperer (Oxford) and Börgers (ELSE) with Dustmann (UCL).

Funding: This project has received support from ELSE’s core funding through Börgers’ teaching buy-out and co-funding through Binmore's Leverhulme chair.

Duration: 2001 – 2003.

Results: While Binmore and Klemperer (2002) survey the design of the UK UMTS auction, Börgers and Dustmann's project aims to carefully describe companies’ bidding behaviour in the UMTS licensing procedures in all member states of the European Union.

Börgers and Dustmann (2001) focus on the auction that took place in the UK in 2000. Their major finding is that some bidding behaviour is difficult to rationalise. The most significant anomaly is that bidders did not seem to have a consistent evaluation of the difference between the value of a large license (i.e. one giving access to much spectrum), and a small license (i.e. one giving access to relatively little spectrum). Their work has prompted discussion among auction experts. The hypothesis that has

been put forward is that some bidders bid with the intention of driving up the prices to be paid by other bidders. If this hypothesis is correct, it has major policy implications: in particular, auction formats that make this type of strategy impossible seem more advantageous.

In ongoing work Börgers and Dustmann are extending their analysis to all member states of the European Union. Their work is the first attempt to provide a careful evaluation of the European experiences with “beauty contests”. Börgers and Dustmann also provide a discussion of “asymmetric designs” which favour new entrants. They point out that these designs resulted in strategic manoeuvres by firms in an attempt to gain favoured status in the auction.

Dissemination: *Prominent publications:* Binmore and Klemperer (*Economic Journal* 2002), Börgers and Dustmann, Rationalising the UMTS Spectrum Bids: The Case of the UK Auction (*ifo Studien*). *Working papers:* Börgers and Dustmann (2001), Strange Bids: Bidding Behaviour in the United Kingdom's Third Generation Spectrum Auction. *Key presentations:* Results from Börgers and Dustmann's project have been presented at a variety of seminars, including a seminar for civil servants in the Radiocommunications Agency that was responsible for the UK spectrum auction. The research has also been presented at conferences on spectrum auctions in Brussels (October 2001) and Munich (November 2001).

Project 4.6: Experimental Evaluation of Auctions

Aims and Objectives: To improve the foundations of real world auction advice by developing further insights into bidding behaviour in experimental auctions.

Researchers: Binmore (ELSE), Curzon Price (ELSE), McCarthy (ELSE), Swierzbinski (ELSE), Tomlinson (ELSE).

Funding: This project has received support from ELSE's core funding through Swierzbinski's teaching buy-out and the funding of Curzon Price, McCarthy, and Tomlinson all of whom are, or have been, full-time ELSE employees.

Duration: 1997 – 2003.

Results: Experimental studies of a variety of auction formats have been undertaken. Most of these experiments have explored issues raised by our advisory work on auctions. Some of the experiments have had to remain confidential because of the consultancy contracts under which they were carried out. This includes, in particular, the experiments carried out for the UK government while preparing the license auctions for third generation mobile telephony.

Some of the research has concerned alternative formats of multi-unit auctions. In particular, ELSE has experimentally implemented a version of Ausubel's innovative auction design.

In the auctions to license third generation mobile telephone operators in Europe, promoting entry has been an important practical concern. When it is common knowledge that some prospective bidders are likely to have higher valuations than others game theory suggests that an auction with a sealed-bid stage is likely to encourage more entry from bidders with lower average values than an open, ascending bid auction. Binmore and Swierzbinski have reviewed the theoretical predictions for auctions with asymmetric bidders, and have started the design of a series of experiments to test these predictions. They plan to conduct and analyse such experiments in 2002– 2003.

Dissemination: This research has been disseminated in consultancy reports and presentations for the UK's Radiocommunications Agency and for British Gas Storage.

Project 4.7: Work Incentives In The Public Sector

Aims and Objectives: To understand better how to incentivise public sector workers.

Researchers: Albano (ELSE), Leaver (ELSE).

Funding: This project has received support from ELSE's core funding through Albano's teaching buy-out and Leaver's post-doctoral research position.

Duration: 2002 – 2003.

Results: The starting point for this research can be seen in recent surveys which have highlighted that reputation and, in particular, the possibility of future private sector employment, are important sources of motivation for workers in the public sector. This project has developed a dynamic model of sector choice to investigate how such career concerns affect the ability of a public sector paying a flat wage to *recruit* and *retain* staff. Preliminary results suggest that transparent performance measures allow the public sector to recruit at lower wages but reduce the quality of its future workforce. Suppressing such information dramatically increases wage bills and only partially eases retention problems.

Dissemination: None yet.

Project 4.8: Mechanism Design and Voting

Aims and Objectives: To investigate the advantages and disadvantages of alternative voting systems. The project plans to apply insights from the general theory of mechanism design to voting.

Researchers: Börgers (ELSE).

Funding: This project has received support from ELSE's core funding through Börgers' teaching buy-out.

Duration: 2000 – 2003.

Results: Börgers has pursued a mechanism design approach to voting procedures. As a first step, Börgers (2000) asks how the costs of participation in voting affect the optimal design of voting procedures. In a very simple context, with private values and only two alternatives, he shows that equilibrium participation rates in voluntary majority voting are too high in comparison to a social optimum. He then studies conditions under which procedures such as voting in a committee dominate voluntary majority voting.

In new work with his PhD student Postl, Börgers now plans to study optimal voting procedures for the case of three alternatives. This is a much-studied area, in which many impossibility results have been obtained. However, Börgers and Postl hope that a Bayesian mechanism design approach will yield a more positive perspective on this field.

Dissemination: *Working papers:* Börgers (2000), *Costly Voting*. *Key presentations:* Research from this project has been presented at a variety of seminars, including seminars at MIT/Harvard, Northwestern University and Cornell University. The research has also been presented in an invited lecture at a conference on mechanism design in Barcelona (November 2001).

Project 4.9: Mechanism Design For Permit and License Trading

Aims and Objectives: To develop policy-relevant insights into the design of auction and markets for environmental permits.

Researchers: Börgers (ELSE), Larson (ELSE), Salmons (ELSE) and Swierzbinski (ELSE).

Funding: This project has received support from ELSE's core funding through Börgers and Swierzbinski's teaching buy-outs and through Larson's post-doctoral research position.

Duration: 2000 – 2003.

Results: The assignment of property rights to an environmental resource together with a mechanism for trading these rights has been an increasingly popular method for regulating environmental externalities. Global warming, the allocation of scarce water, local air pollution, and the allocation of scarce radio spectrum are examples of environmental problems for which market-based policy instruments have been used or proposed. We have begun to study how game theory can be applied to assess and improve the design of market-based institutions for trading the rights to selected environmental resources.

Some of the research in this area is carried out under external research contracts. Börgers and Larson are under contract with the Radiocommunications Agency. This

contract is a joint project of ELSE and the consulting company NERA. Salmons and Swierzbinski are involved in a contract with the Environment Agency.

Our research in this area reviews the theoretical literature on micro market structures, constructs models for the simulation of such markets, and derives policy recommendations. Some of the work focuses on licenses for radio spectrum; other research focuses on markets for environmental permits.

Dissemination: Insights from this project are disseminated in consultancy reports and meeting presentations with the Radiocommunications Agency and with the Environment Agency.

5. Automated Trading and Negotiation

Project 5.1: E-Commerce and Price Formation

Aims and Objectives: To study the impact of electronic trading arrangements on the behaviour of firms and consumers, and the implications for market outcomes.

Researchers: Ulph (ELSE), Vaughan (ELSE), Vulkan (Said Business School, formerly ELSE).

Funding: This project has received support from ELSE's core funding through Ulph and Vaughan's teaching buy-outs. Support for Ulph and Vulkan has also been received from an ESRC grant on "Economic Implications of Trading with Smart Agents".

Duration: 1997 – 2003.

Results: It is often argued that e-commerce gives firms scope to offer consumers customised products at customised prices. Ulph and Vulkan have focused on this issue of price discrimination in the final phase of their ESRC funded project "Economic Implications of Trading with Smart Agents" which came to a conclusion in Spring 2000.

In the first of two related papers on this topic, Ulph and Vulkan (2000a) consider the case where firms can customise prices but not products. They show that there are two effects of price discrimination: (i) a rent extraction effect that allows firms to extract greater profits from consumers and (ii) a competition effect that lowers profits. They show that unless there is a very high degree of consumer loyalty – in a sense that is made precise – then the second effect dominates the first, and firms are worse off by price discriminating. So in many cases, even if e-commerce makes discrimination feasible, it still may not be adopted.

Ulph and Vulkan (2000b) extend this analysis to the case where firms can also customise products and highlight the following points. First, the greater the degree of customisation, the more likely it is that firms will choose to price discriminate. Second, the incentive to customise products is greater when firms price discriminate. Third, firms end up in a prisoner's dilemma in which they are driven to both product and price customisation, even though the intense competition that they face ensures that they are all worse off as a result.

Ulph and Vaughan's research on the effect of recent developments in electronic trading arrangements on market equilibria is due to conclude in 2003. Electronic data interchange (EDI) may result in the practical elimination of (i) search costs for the purchase of goods by consumers and (ii) delays in the monitoring of competitors' behaviour. Ulph and Vaughan aim to establish whether EDI will result in a competitive market outcome (via the elimination of search costs for consumers), or implicit collusion and hence higher prices (via improved monitoring of competitors).

Early results cast doubt on the conventional wisdom that a lower price equilibrium will always result.

Dissemination: *Working Papers:* Ulph and Vulkan (2000a), Electronic Commerce and Competitive First-Degree Price Discrimination, Ulph and Vulkan (2000b), E-Commerce, Mass Customisation and Competitive First-Degree Price Discrimination.

Project 5.2: E-Commerce and Negotiations

Aims and Objectives: To apply game theoretic techniques to the design of negotiation algorithms for use by autonomous software agents in electronic commerce.

Researchers: Binmore (ELSE), Vulkan (ELSE), in collaboration with Jennings (Southampton), Priest (Hewlett Packard), Sandholm (Northwestern).

Funding: This project has been funded through Binmore's Leverhulme research professorship, and through a grant from the EPSRC for research on "Bargaining by Automata Engaged in Negotiations".

Duration: 1999 - 2002.

Results: The worldwide web gives rise to the possibility of automated negotiations. This research aims to develop negotiation algorithms for use by autonomous software agents in electronic commerce. We anticipate that such algorithms will be important whenever negotiations have to be conducted very quickly and frequently (i.e. when human traders would be unable to process the relevant information). An example would be the negotiations between large users of communications facilities and telecommunications network providers over required bandwidth and price.

Binmore and Vulkan (1999) and Vulkan (1999a,b) develop a general classification scheme for automated negotiations in e-commerce. In joint work with Priest, Vulkan has provided a specification for an on-line algorithm for trading in communication bandwidth. The algorithm uses the tools of statistical learning theory to test on-line whether the trading environment is consistent with the agent's model of the world. If the environment is stable and is consistent with the agent's model, then the agent best responds to its beliefs (i.e. chooses the bid which maximises the users expected utility). If the trading environment is not stable then the algorithm switches to its transitory mode. Finally, the algorithm allows for new models of the environment to replace old ones. Vulkan and Priest show that in stationary environments the algorithm quickly finds the optimal strategy but is also responsive to changes in the environment.

Deadlines are common in e-commerce application, not least because they provide users with an easy way of expressing their time-preferences (see, for example, the use of deadlines in Internet auctions, and reverse auctions, such as Priceline.com). To explore this issue, Sandholm and Vulkan (1999) develop a continuous time bargaining model in which agents face firm deadlines. Since each agent's deadline is private

information, there is a disadvantage in making offers. Any offer, with the exception of demanding everything for oneself, reveals the proposer's deadline cannot be very long. Moreover, the proposer will know that they have offered too much if their offer gets accepted (i.e. they would have done better by out-waiting their opponent). Sandholm and Vulkan show that a sequential equilibrium exists where agents do not agree to a split until the first deadline, at which time the agent with the later deadline receives the whole surplus. Based on this understanding, they suggest a simple e-commerce protocol for automated negotiations with deadlines. Each agent sends one message to the protocol, which then assigns the whole surplus to the agent with the latest deadline. They show that this simple protocol is in many ways “optimal”. Agents have a clear dominant strategy, which is to report their true deadline, and optimal behaviour does not require agents to construct or update beliefs about each other.

Vulkan (2001) develops a model in which users choose agents that are then matched on various locations (hosts). Hosts will normally check the agents (i.e., the code) to verify that it is compatible with the communication protocol. Vulkan shows that users will choose agents who reveal parts of their code in order to co-ordinate on welfare improving outcomes which otherwise would not have been supported in equilibrium.

Dissemination: *Prominent publications:* Binmore and Vulkan (*Netonomics* 1999), Vulkan (*Economic Journal* 1999, *Wirtschaftspolitische Blätter* 1999, *Games and Economic Behavior* 2001). *Working papers:* Sandholm and Vulkan (1999), *Bargaining with Deadlines.*

Project 5.3: Trust and the Internet

Aims and Objectives: To investigate conditions under which the trust required for anonymous electronic transactions emerges or is undermined. The project will use theoretical, experimental and empirical research methods.

Researchers: Huck (ELSE) and Joffe (ELSE), in collaboration with Rogers (UCL), Bohnet (Harvard), Ortmann (CERGE), and Tyran (St Gallen).

Funding: This project has received support from ELSE’s core funding through Huck’s teaching buy-out and through research assistance for Joffe. Co-funding comes from the Russell Sage Foundation and a Research Grant from the University of St. Gallen.

Duration: 2002 – 2005.

Results: Trade and information exchange requires trust among the participating agents. We are investigating these trust issues in various projects. Joffe, in joint work with Rogers (UCL) is investigating the interaction between medical information available on the Internet and patient’s needs to obtain information in GP consultations.

Huck, in joint work with Bohnet (Harvard) and Tyran (St. Gallen) is studying the evolution of trust in a laboratory environment. Which institutions help to establish

trust and trustworthiness in an environment where subjects are unable to trust each other in an anonymous one-shot environment? How can strategic incentives for trustworthiness be distinguished from an intrinsic motivation to be honest? How much social cohesion is needed for trust to develop? These are the questions on which the research focuses. First results indicate the importance of feedback facilities about past transactions (as famously employed by ebay).

In related research, Huck and Ortmann study how various degrees of law enforcement in Internet transactions foster trust and honest trade in Internet markets. Surprisingly, they show that medium enforcement level may induce higher degrees of non-fraudulent behaviour than high enforcement levels.

Dissemination: None yet.

6. Industrial Organisation

Project 6.1: Cooperation in Research and Development

Aims and Objectives: To predict the extent to which firms will share research results, and to evaluate whether such sharing can overcome market failures, such as excessive duplication and underinvestment in Research and Development. The project seeks to develop theoretical models, and to implement these models empirically.

Researchers: von Graevenitz, Ulph, in collaboration with Barba Navaretti (Milan), Beath (St Andrews), Katsoulacos (Athens), Owen (Nantes), Siebert (Berlin).

Funding: This project has received support from ELSE's core funding through Ulph's teaching buyout. Additional support has been received from the ESRC through a post-doctoral fellowship for von Graevenitz. Further support has been received from the European Community through TSER projects on "Innovation and Productivity", "Science and Technology Policies to RJVs". Funding was also received from CNRS (France) and from NBER (United States). Co-funding in the form of payments for data has been provided by the Wissenschaftszentrum Berlin via von Graevenitz' co-author, Siebert.

Duration: 1995 – 2003.

Results: A game theoretic model of information sharing in Research Joint Ventures (RJV) has been developed (Katsoulacos and Ulph 1998). This model has been used to predict how different factors influence whether RJVs form, and how much information will be shared by RJVs. For example, it has been shown that RJVs may be more likely to form when firms are in the same industry. Also, the choice between sharing knowledge through RJVs and sharing knowledge through licensing has been analyzed. The effects of competition on the performance of RJVs have also been examined theoretically (von Graevenitz, Does competition affect how firms should collaborate on R&D?, working paper). It was shown that RJVs are particularly beneficial in less competitive markets. The implications of RJVs for entry have been studied by Ulph, Beath, and Katsoulacos (Research Joint Ventures and Entry Deterrence, working paper). It was shown when RJVs promote and when they deter entry. A model of environmental RJVs was also developed (Ulph, and Ulph, Katsoulacos, book chapter). This model shows that RJVs perform well when damages are low, but poorly when damages are high.

Empirical work has been undertaken that confirms predictions about the formation of RJVs for European data (Bussoli *et al.* 2002). Siebert and von Graevenitz are undertaking further work which examines empirically how firms choose between RJV formation, licensing and direct competition. In this project they also study how RJV formation affects firms' research portfolios. To do this we use data for the semiconductor industry in conjunction with patent data.

Dissemination: *Prominent publications* include: Katsoulacos and Ulph (*Journal of Industrial Economics*, 1998) and Ulph, Ulph and Katsoulacos' book contribution.

Working papers include Ulph, Beath and Katsoulacos (Research Joint Ventures and Entry Deterrence), Bussoli et al. (Information Sharing, Research Co-Ordination and Membership of Research Joint Ventures). *Key presentations* include Ulph's 2000 lecture at the 'Technology Policy And Innovation: Historical and Economic Perspectives' conference in Paris and von Graevenitz' presentation at the conference on 'Innovation and Supermodularity' at CIRANO in Montreal 2000. Further presentations were held at the EARIE conference in Turin 1999. In January 1998 ELSE hosted a workshop on "Competition Policy and Innovation".

Project 6.2: Institutions and Innovation Systems

Aims and Objectives: To understand how institutions affect firms' choices about the type of research to undertake, the effort firms put into innovation and their chances of success. To establish how institutions should be designed to provide optimal incentives for innovation. The project seeks to develop theoretical models, and where possible to test these empirically.

Researchers: von Graevenitz, Ulph, in collaboration with Beath (St Andrews), Encacoua (Paris), Hall (Berkeley), Menezes-Filho (USP), Poyago-Theotoky (Nottingham), Soskice(Duke), Ulph (Southampton), van Reenen (UCL).

Funding: This project has received support from ELSE's core funding through Ulph's teaching buyout. Additional support has been received from the ESRC through a post-doctoral fellowship for von Graevenitz. Further funding has come from the European Community through TSER projects on "Growth, Inequality and Training" and on "Product Markets, Financial Markets and the Pace of Innovation in Europe".

Duration: 1995 – 2003.

Results: A theoretical model predicting the impact of unionisation on research and development has been developed (Ulph and Ulph 1998 and 2001). It has been shown that increasing unionisation does not necessarily result in a reduction of R&D investment.

Empirical evidence on the role of unions in the determination of R&D has been provided in Menez-Filho, Ulph, and van Reenen (1998a and 1998b). Further work to examine the impact of labour- and financial market institutions on the choice of research projects by companies is in progress. We seek to show that institutions affect the specialization of industries in different countries.

A new framework for analysing the link between fundamental and applied research, and between universities and firms, was developed (Beath et al., "Optimal Incentives for Income-Generation within Universities", 2001). The model was used to explore which policies universities should adopt towards the (implicit) taxation of income from applied research.

A model to study the effects of variations in the degree of knowledge diffusion was developed (Ulph and Encauoa, working paper, 2000). The model captures the effects of increased competition in product markets on the incentives to invest in R&D. The model shows that markets for technology licenses are crucial if firms in less developed countries are to generate more growth.

Dissemination: *Prominent publications* include: Menez-Filho, Ulph, and van Reenen (*Industrial and Labor Relations Review* 1998, *European Economic Review* 1998) Ulph and Ulph (*European Economic Review* 1998, *Scandinavian Journal of Economics* 2001). Working papers include: Ulph and Encauoa, (Catch-up Versus Leapfrogging: The Effects of Competition, 2000), Beath et al. (Optimal Incentives for Income-Generation within Universities).

Project 6.3: Price Transparency and the Single European Currency

Aims and Objectives: To understand the implications of the single European currency for competition and for consumers. The objective of the project is to develop a theoretical framework in which the implications of the Euro for product market competition and consumer welfare can be understood.

Researchers: Ulph, Vaughan, and Curzon-Price (all ELSE) in co-operation with researchers from the Centre for Economic Policy Research.

Funding: This project was funded by the European Commission (DGII). It also received support from ELSE's core funding through Ulph's teaching buyout.

Duration: 1998 – 2000.

Results: A model was developed which encompasses the three principal avenues by which an increase in price transparency may be expected to influence market equilibria. Firstly, by making price comparisons between products easier, competition may be enhanced. Secondly, by making prices more observable for competitors, implicit collusion may be facilitated, and thus competition reduced. Thirdly, the arbitrage possibilities between markets may be increased, which is of benefit to the consumer.

Dissemination: A report for the European Commission was provided.

Project 6.4: Learning Stability of Price Dispersion

Aims and Objectives: To understand the determinants of the extent of price dispersion. The goal of the project is to develop a theoretical model of learning and price dispersion.

Researchers: Seymour (ELSE), in co-operation with Hopkins (Edinburgh).

Funding: This project received funding out of ELSE's core grant by providing a teaching buyout to Seymour.

Duration: (1999-2001)

Results: In many markets it is possible to find rival sellers charging different prices for the same good. Earlier research has attempted to explain this phenomenon by demonstrating the existence of dispersed price equilibria when consumers must make use of costly search to discover prices. Seymour and Hopkins have asked whether such equilibria can arise when sellers adjust prices adaptively in response to current market conditions. With consumer behaviour fixed, convergence to a dispersed price equilibrium is possible in some cases. However, once consumer learning is introduced, the monopoly outcome first found by Diamond is the only stable equilibrium.

Dissemination: *Prominent publications:* Hopkins and Seymour (*International Economic Review*, 2002).

Project 6.5: Dynamic Price Competition

Aims and Objectives: To understand the factors which facilitate implicit collusion in price competition. The focus of the project is on the development of a theoretical model in which consumers are long-lived.

Researchers: Matros, in collaboration with Dutta (Columbia University) and Weibull (Stockholm).

Funding: This project received funding out of ELSE's core grant as Matros is a fully paid post-doctoral research fellow of ELSE.

Duration: 2000 – 2000.

Results: In the textbook model of dynamic Bertrand competition, competing firms meet the same demand function every period. This is not a satisfactory model of the demand side if consumers can make intertemporal substitution between periods. Each period then leaves some residual demand to future periods, and consumers who observe price under-cutting may correctly anticipate an ensuing price war and therefore postpone their purchases. Accordingly, the interaction between the firms no longer constitutes a repeated game, and hence falls outside the domain of the usual Folk theorems. We analyse collusive pricing in such situations, and study cases in which consumers have perfect and imperfect foresight and varying degrees of patience. It turns out that collusion against patient and forward-looking consumers is easier to sustain than collusion in the textbook model.

Dissemination: ELSE working paper by Matros, Dutta and Weibull (2002).

Project 6.6: Oligopoly Experiments

Aims and Objectives: To understand which behavioural forces shape oligopolistic market outcomes. To develop experimental set-ups which can shed light on the empirical validity of the predictions of oligopoly theory.

Researchers: Huck, in collaboration with Fonseca (Royal Holloway), Konrad, (Wissenschaftszentrum Berlin), Müller (New York University), Normann (Royal Holloway), Oechssler (Bonn), and Vriend (QMW).

Funding: The main funding for this project comes from ELSE's core grant, though Huck's teaching buyout. Co-funding in the form of payments to experimental subjects has been provided by the German Science Foundation (DFG) via Huck's german co-authors.

Duration: 2001 – 2005.

Results: Huck, Müller, and Normann (2001) studied exogenous Stackelberg duopolies and compared them to Cournot markets. They find that a leader-follower structure increases total welfare as predicted by the theory. However, leaders are not able to exploit their full theoretical advantage as followers' empirical reaction function is flatter than predicted by theory. Huck and Wallace (2002) study a similar set-up where second movers have to submit full strategies. Their findings corroborate the findings of the first study.

Huck, Müller, and Normann (2002) study a model that predicts the endogenous emergence of a leader-follower structure. The prediction fails in the laboratory. Again this is due to the very aggressive behaviour of followers. In an unpublished paper Fonseca, Huck, and Normann analyse whether the theory performs better when firms have different costs. But, yet again, Cournot outcomes result much more frequently than Stackelberg outcomes, illustrating the robustness of the Cournot equilibrium prediction.

The stability of Cournot's best-reply process is tested in Huck, Normann, and Oechssler (2002) where it is found that adaptive behavior is more stable than a pure best-reply process predicts. This is due to imitation.

The Cournot prediction is also tested in a series of experiments by Huck, Normann and Oechssler (Two are Few and Four are many: Number Effects in Experimental Oligopoly) who study 2-, 3-, 4-, and 5-firm oligopolies in a unified frame. Their main finding is that collusion is only an issue in duopolies. In related research Huck, Konrad, Müller, and Normann (Mergers and the Perception of Market power: An experimental study) study merger activity in Cournot markets. They find that merged firms tend to behave more aggressively than theoretically predicted which seems due to pre-merger aspiration levels.

Finally, Huck, Müller and Vriend (2002) study competition in markets where location is the only strategic variable.

Dissemination: *Prominent publications* include: Huck, Müller, and Normann (*Economic Journal*, 2001, *Games and Economic Behavior*, 2002), Huck, Normann, Oechssler (*International Journal of Game Theory* 2002), Huck, Müller and Vriend (*Economic Inquiry* 2002). Working papers include: Huck, Normann and Oechssler (Two are Few and Four are many: Number Effects in Experimental Oligopoly), Huck, Konrad, Müller, and Normann (Mergers and the Perception of Market power: An experimental study).

Project 6.7: The Value of Public and Private Information in Markets

Aims and Objectives: To understand the interaction between firms and consumers when consumers are imperfectly informed about product quality.

Researchers: Ottaviani (LBS and ELSE), in collaboration with Moscarini (Yale) and Prat (LSE).

Funding: This project received funding out of ELSE's core grant through Ottaviani's teaching buyout.

Duration: 1995 – 2000.

Results: How do property rights and competition affect the aggregation of dispersed information? Ottaviani and Prat (2001) show that, public affiliated information has positive value in monopoly. A monopolist selling to a privately informed buyer always prefers to commit to publicly reveal information affiliated to the valuation of the buyer.

This result sheds light on the possible effect of information technology on competition. For example, the internet allows sellers to reveal information about their products at very low cost. According to the result obtained for the case of monopoly, making information publicly available is beneficial to the seller, but not necessarily to the buyer. When the seller provides more information about the product, buyers are more likely to know better the match between their idiosyncratic taste and features of the goods sold.

The result on the value of public information has important implications for the dynamics of monopoly pricing with social learning. Consider a monopolist selling to a sequence of privately informed buyers deciding one after the other. For the sake of illustration, focus on a two-period model where the price offered as well as the purchase decision of the first buyer are publicly observed by the second buyer.

By the choice of the price offered in the first period, a patient monopolist trades off static profit maximisation with the value of future public information revelation. The optimal price then results in the revelation of not less public information than the myopically optimal price. As shown by Moscarini and Ottaviani (2001), competing price-setting sellers do not necessarily benefit from revelation of public information when the buyer has private information on the relative valuation of the goods.

Dissemination: *Prominent publications* include: Moscarini and Ottaviani (*Journal of Economic Theory*, 2001), Ottaviani and Prat (*Econometrica*, 2001).

Project 6.8: Comparative Advertising

Aims and Objectives: To explore when comparative advertising is welfare improving, and when there is a conflict between firms' private incentive and welfare concerns. The project will develop a theoretical framework for analysing these issues.

Researchers: Albano, in collaboration with Battaglini (Princeton).

Funding: From 2002 onwards his project will be funded from ELSE's core grant, through Albano's teaching buyout. Previously, the project was funded by UCL's economics department through Albano's teaching buyout.

Duration: 2000 – 2003.

Results: Albano and Battaglini are in the process of developing the modelling framework and they have begun to prove theoretical results, but this project is not yet complete.

Dissemination: None yet.

Project 6.9: Quality Certification

Aims and Objectives: To understand the possible benefits and costs of certification systems in markets in which consumers are uncertain about the quality of the goods that they buy.

Researchers: Albano, in collaboration with Lizzeri (NYU), Newman (UCL) and Sahuguet (ECARES, Brussels).

Funding: From 2002 onwards his project will be funded from ELSE's core grant, through Albano's teaching buyout. Previously, the project was funded by UCL's economics department through Albano's teaching buyout.

Duration: 2000 – 2003.

Results: Albano and Lizzeri (2001) study the effect of the presence of a certification intermediary in an environment where information asymmetries are particularly severe. The intermediary improves the information that buyers have about quality. This in turn increases the incentives that the seller has to provide high-quality goods. Efficiency is increased by the presence of the intermediary, but quality is underprovided in equilibrium relative to full information. The intermediary can implement the optimal policy in many ways. The amount of information revealed ranges from full disclosure to partial, noisy disclosure.

In ongoing research Albano and Newman develop a model of a market in which firms' product quality has two dimensions: a measurable and a non-measurable dimension (e.g., punctuality and safety of transportation services provided by rail companies). It is assumed that consumers cannot commit to contracts, so the market provides implicit rather than explicit incentive. An intermediary for certification has been introduced into the model. The intermediary raises the informativeness of the signal on the measurable dimension. Albano and Newman are in the process of exploring circumstances under which the certification activity worsens the market outcome.

Albano and Sahuguet are developing a model that will explain under what circumstances a leading firm might benefit from subsidising an intermediary's investment in testing technology. Higher quality standards might force smaller (possibly less efficient) firms out of the market, thus allowing the leading firm to monopolise the market.

Dissemination: *Prominent publications* include: Albano and Lizzeri (*International Economic Review* 2001).

Project 6.10: Regulators' Incentives

Aims and Objectives: To examine how incentives can be provided to industry regulators. The project will develop theoretical predictions and will test these predictions on empirical data.

Researchers: Leaver (ELSE).

Funding: From Spring 2002 this project is funded by an ESRC post-doctoral fellowship. Previously, the project was funded out of ELSE's core grant by funding Leaver as a full-time researcher. It is anticipated that further funding will be provided by ELSE in 2003.

Duration: 2001 – 2003.

Results: Leaver has developed in her PhD dissertation a theoretical model which suggests that regulators which are appointed with short-term contracts set policies that are excessively lenient. The regulator's aim is to remain quiet and maintain their professional reputation ("minimal squawk"). In new work Leaver tests this prediction by exploiting variation in statutory term-length across US State Public Utility Commissions. Firm-level panel data from the regulation of the US electric industry (1980-90) offers strong support for the model: electric utilities are significantly less likely to face rate reviews and set significantly higher prices when their regulators serve for shorter terms.

The above empirical study identified that statutory terms of office for regulatory commissioners play a role in shaping regulatory policy, with shorter terms of office resulting in more lenient policies. "Minimal squawk" behaviour is one explanation; an alternative is that longer terms facilitate learning. In a second project Leaver attempts

to distinguish between these two hypotheses. Work to date has focused on developing a dynamic model of regulatory decision-making in the presence of career concerns to illustrate how "minimal squawk" behaviour evolves over time. This model will then be extended to allow for skill accumulation. The aim is to produce testable predictions that can be taken to data obtained on the career paths of individual regulators.

Dissemination: *Working paper:* Leaver (2002), Bureaucratic Minimal Squawk Behaviour: Theory and Evidence from US Regulatory Policy. *Key presentations* include: Wallis Institute for Political Economy (Rochester, March 2002), Royal Economic Society Conference (Warwick, March 2002), CEPR / SITE Conference on Incentives and Beyond (Stockholm, May 2002) and European Economic Association (Venice, August 2002).

Project 6.11: Experts and Forecasting

Aims and Objectives: To examine the incentives of experts, such as investment advisors. The project will develop theoretical predictions and will test these predictions on empirical data.

Researchers: Ottaviani (LBS and ELSE), in collaboration with Garidel-Thoron (formerly ELSE) and Sørensen (Copenhagen), as well as Sozou (LSE, formerly ELSE), in collaboration with Goodyear and Gallivan).

Funding: Between 1997 and 2000 this project received funding from ELSE's core grant through Ottaviani's teaching buyout and Sozou's position.

Duration: 1997 – 2003.

Results: What happens when the information relevant to decision makers is possessed by specialists? Motivated by policy questions raised by the Financial Services Authority (the regulator of the UK financial industry), Ottaviani and de Garidel (2000) have developed the theory of strategic communication and applied it to the problem of financial advice. Financial advisers give information to individual investor. In order to account for the regulators' typical concern about unsophisticated investors, investors are allowed to have varying degree of strategic sophistication. Incentives for truthful information disclosure, information acquisition, and the role of explicit monetary transfers have been analysed.

In a series of papers, Ottaviani and Sorensen have proposed two theories of strategic behaviour by professional forecasters. According to the reputational cheap talk theory, forecasters aim at convincing the market that they are well informed. The market evaluates their forecasting ability by comparing the forecasts with the realisations. Empirical implications depend on the level of market rationality. If the market has naive views on forecasters' behaviour, forecasts are biased toward the prior mean. Otherwise, equilibrium forecasts are unbiased but systematically less precise than if the forecasters were not strategic.

According to forecasting contest theory, the rules of competition among forecasters are pre-specified. As an illustration, forecasts are excessively differentiated in equilibrium of a winner-take-all limit contest. The availability of data allows to test for the presence of strategic behaviour in forecasting and to compare these two theories.

In a different project Goodyear, Gallivan, and Sozou (1997, book chapter) analysed whether queuing theory can be used to forecast waiting times in hospitals. In a follow-up study Goodyear, Sozou, and Gallivan (A Study of Finite-period Models of Waiting Times in Hospitals, working paper) applied numerical queuing models to forecast actual waiting times in a trauma department.

Dissemination: *Working papers:* Ottaviani and Sørensen (Professional Advice: The Theory of Reputational Cheap Talk, The Strategy of Professional Forecasting, Rank-order and Forecasting Contests) as well as a book chapter by Goodyear, Gallivan, and Sozou (1997).

Project 6.12: Mergers Without Synergies

Aims and Objectives: To understand how mergers might be profitable even if they do not induce cost advantages. To study how internal organization of a merged firm affects market structure. To understand mergers in more complex strategic environments.

Researchers: Steffen Huck (ELSE) in collaboration with Kai Konrad (Wissenschaftszentrum Berlin) and Wieland Müller (NYU).

Funding: This research is supported by ELSE core funding via Huck's teaching buyout.

Duration 2001-2003: Huck, Konrad, and Müller (Profitable Horizontal Mergers Without Cost Advantages: The Role of Internal Organization, Information and Market Structure, working paper) study a model in which two firms that merge are kept as separate, profit-maximizing units. They show that when production is not instantaneous and information about production decisions flows more easily between affiliated firms than between competitors, bilateral mergers can be profitable even if demand and cost are linear. Key to this result is that the merged firm will have some endogenous commitment power. This model helps to resolve Salant, Switzer and Reynolds' "merger puzzle" and explains why, in contrast to all established theoretical merger models, competitors of merged firms sometimes suffer.

Huck and Konrad (Merger Profitability and Trade, working paper) study mergers in international markets where governments may use instruments of strategic trade. They show that in the presence of strategic trade bilateral mergers can be profitable even if they do not induce cost advantages. Further, they may increase welfare in the country that hosts the merging firms. Profits of foreign firms are reduced and so is foreign welfare. These results hold for quantity and price competition as well as for competition in contests. The paper helps to explain the merger between Boeing and

McDonnell Douglas that was welcomed by US but not by European competition authorities.

Dissemination: *Working papers:* Huck, Konrad, and Müller (Profitable Horizontal Mergers Without Cost Advantages: The Role of Internal Organization, Information and Market Structure), Huck and Konrad (Merger Profitability and Trade) *Key presentations* include: (Frankfurt, St. Gallen, Humboldt, Tokyo) and conference meetings (Ottobeuren, European Economic Association 2002).

Annex B: Outputs

1. Nominated Publications

The ESRC has invited us to nominate ten publications comprising best examples of the quality of the Centre's work across its programme.

- 1) Binmore, K. (1998), *Game Theory and the Social Contract, Volume 2: Just Playing*. Cambridge (MA): MIT Press.
- 2) Binmore, K. and L. Samuelson (1999), Evolutionary Drift and Equilibrium Selection, *Review of Economic Studies*, 66, 363-393.
- 3) Börgers, T., and R. Sarin (1997), Learning Through Reinforcement and Replicator Dynamics, *Journal of Economic Theory* 77 (1997), 1-14.
- 4) Dunbar, R. I. M. (1996), Determinants of Group Size in Primates: A General Model, in: W. Runciman, J. Maynard Smith, J., and R. I. M. Dunbar (editors), *Evolution of Social Behaviour Patterns in Animals and Man*, Proceedings of the British Academy 88, Oxford: Oxford University Press, 33-57.
- 5) Heyes, C. M. (1998), Theory of Mind in Nonhuman Primates, *Behavioral and Brain Sciences*, 21, 101-1048.
- 6) Jehiel, P., and B. Moldovanu (2001), Efficient Design with Interdependent Valuations, *Econometrica*, 69, 1237-1259.
- 7) Miller, G. (2000), *The Mating Mind: How Sexual Choice Shaped The Evolution of Human Nature*, New York: Doubleday.
- 8) Plotkin, H. (1997), *Evolution in Mind*, London: Allan Lane (Penguin).
- 9) Shanks, D., R. J. Tunney, and J. D. McCarthy (2002), A Re-examination of Probability Matching and Rational Choice, *Journal of Behavioral Decision Making*, 15, 233-250.
- 10) Ulph, D., and A. Ulph (2001), Strategic Innovation with Complete and Incomplete Labour Market Contracts, *Scandinavian Journal of Economics*, 103, 265-282.

2. Books

Barrett, L., and Dunbar, R. I. M. (2000), *Cousins: Our Primate Relatives*, London: BBC Worldwide.

Barrett, L., R. I. M. Dunbar, and J. E. Lycett (2002), *Human Evolutionary Psychology*, Basingstoke: Palgrave/Macmillan, and Princeton: Princeton University Press.

Binmore, K. (1998), *Game Theory and the Social Contract, Volume 2: Just Playing*, Cambridge (MA): MIT Press.

Cowlshaw, G., and R. Dunbar (2000), *Primate Conservation Biology*, Chicago: Chicago University Press.

Deissenberg, C., R. Owen, and D Ulph (editors) (1997), *The Economics of European Integration*, Oxford: Basil Blackwell.

Dunbar, R. I. M. (1995), *The Trouble with Science*, London: Faber and Faber.

Dunbar, R. I. M. (1996), *Grooming, Gossip and the Evolution of Language*, London: Faber and Faber.

Dunbar, R. I. M., C. Knight, and C. Power (editors) (1999), *The Evolution of Culture: An Interdisciplinary View*, Edinburgh: Edinburgh University Press.

Harvey, N. (editor) (2001), *Studying Judgment: Models and Methods*, Hove: Psychology Press.

Heyes, C. M., and B. G. Galef (editors) (1996), *Social Learning and the Roots of Culture*, San Diego: Academic Press.

Heyes, C. M., and L. Huber (editors) (2001), *The Evolution of Cognition*, Cambridge (MA): MIT Press.

Heyes, C. M., and D. Hull (editors) (2001), *Selection Theory and Social Construction: The Evolutionary Naturalistic Epistemology of Donald T. Campbell*, Albany (NY): SUNY Press.

Lamberts, K., and D. Shanks (editors) (1997), *Knowledge, Concepts and Categories*, Hove: Psychology Press.

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Shanks, D. (1995), *The Psychology of Associative Learning*, Cambridge: Cambridge University Press.

Shanks, D., K. Holyoak, and D. Medin (editors) (1996), *The Psychology of Learning and Motivation, Volume 34: Causal Learning*, San Diego (CA): Academic Press.

Shanks D. (editor) (1997), *Human Memory: A Reader*, London: Arnold.

Vulkan, N. (2002), *The Economics of E-Commerce: A Strategic Guide to Understanding and Designing the Online Marketplace*, Princeton: Princeton University Press, forthcoming.

Ken Binmore also edits a series of books on “Economic Learning and Social Evolution”, published by the MIT Press. The following books have so far appeared in this series:

1. Samuelson, L., *Evolutionary Games and Equilibrium Selection*, 1997.
2. Fudenberg, D., and D. Levine, *The Theory of Learning in Games*, 1998.
3. Binmore, K., *Game Theory and the Social Contract, Volume 2: Just Playing*, 1998.
4. Durlauf, S., and P. Young (editors) (2001), *Social Dynamics*, 2001.

3. Book Chapters

Barton, R., and R. I. M. Dunbar (1997), Evolution of the Social Brain, in: A. Whyten and R. Byrne (editors), *Machiavellian Intelligence II*, Cambridge: Cambridge University Press, 240-263.

Beath, J., Y. Katsoulacos, and D. Ulph (1995), Game-Theoretic Models of Technological Change, in: P. Stoneman (editor) *Handbook of the Economics of Innovation and Technological Change*, Oxford: Basil Blackwell.

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Dunbar, R. I. M., and Lycett, J. (1998), Human Social Networks: A Report on the FirstJet Send Trial, Report for Hewlett Packard Research.

Dunbar, R. I. M. and others (2000), The Use of Primates Within the U.K. Under ASPA, Report to the Home Office Animal Procedures Committee.

Dunbar, R. I. M., D. Dickins, and R. Hill (2000), Showering Behaviour: The Effects of Using Bathing Aids, Report for Unilever Laboratories.

Gallivan, S., P. Sozou and R. Jackson (1997), Complexity Theory and Computational Mathematics: Potential Applications in Health Care, Report to the Department of Health.

Hernando, A., D. Harbord and G. von Graevenitz, Market Definition in European Sports Broadcasting, Report for the European Commission.

Heyes, C. M., E. Ray, and M. Shaftoe (1999), Imitation and Refreshment, Technical Report AGR 11378, Unilever Research.

Sozou, P., S. Gallivan, and R. Jackson (1996), Modelling the Evolution of Health Care Provision: A Demonstrator Study, Report to the Department of Health.

Thomas, J., and R. M. Seymour (1998), Data Analysis and Hypothesis Testing of CDE's Armoured Vehicle Supply Chain Database, A report for the UK government's Department of Trade and Industry (DTI).

Ulph, D. (1996), Report for DG-II of the European Commission on the Economics of Globalisation.

Ulph, D., and R. Vaughan (2000), Contract Theory and the Public Private Partnership, A Report for the Industrial Society.

Ulph, D. and Vaughan, R. (2001) Price Transparency and Market Equilibria, Report for DG-II of the European Commission.

Vaughan, R. (1996), Distributional Issues in Competition Policy, Report for the Office of Fair Trading.

Vaughan, R. (1999), Distributional Issues in Welfare Assessment and Consumer Affairs Policy, Office of Fair Trading Report.

9. Conferences and Seminars

M. Agastya

1995: University of Tokyo, New Delhi (Conference on Economic Theory and Social Choice).

1996: Stony Brook (Social Learning Conference), Pennsylvania State University, University of Pittsburgh, Harvard Business School.

1997: Bank of England, Kyoto University, Essex, Indira Gandhi Institute for Development Research, Southampton.

1998: University of Waterloo, University of Windsor, Boston University, Pennsylvania State University, University of Western Ontario.

1999: Waseda University.

G.-L. Albano

2000: Università di Brescia.

2001: Royal Holloway College, London Business School, Exeter.

2002: Namur, Université Libre de Bruxelles

K. Binmore

1995: London (ESRC Beliefs and Behaviour Programme; joint presentation with R. Vaughan), LSE, Wisconsin, University of Catania, Oslo.

1996: Harvard, LSE, UK Treasury, Vienna Institute, Yale (Economic Values and Organisation Conference), Institute of Economics Affairs, Tilburg, Milan (Conference on Foundations of Game Theory), UK Department of Trade and Industry, Houston (Public Choice Meeting), Iowa, Bayreuth (Wittgenstein Lectures), Paris (Conference on Evolutionary Economics), Paris, Queen Mary and Westfield College, Florence, Namur, Royal Holloway College, Amsterdam (Conference on Experimental Economics), Caen.

1997: Hamburg, Bank of Italy, Bank of England, NERA London, Rutgers, Bank of Spain, Johns Hopkins, Edinburgh, New Orleans (Keynote Lecture at *Utilitas* Conference), Tokyo, Lund, Alicante, Bank of Spain, Jena, Sussex, Nottingham, South Carolina, Birmingham, Budapest, LSE, Herriott Watt (British Psychological Society Conference), Cortona.

1998: University of Massachusetts, Tilburg, Essex, Liverpool, Johns Hopkins.

1999: Michigan, Linz (Austrian Economic Association), Barcelona, Imperial College, London Business School, Nottingham (Royal Economic Society), UK Treasury, UCL (lunch hour lecture), Pompeu Fabra, Mannheim, Munich, Vienna, Duke, Amsterdam, Montreal, Notre Dame, Wisconsin, Michigan, Helsinki, New York.

2000: Oslo, Stockholm, Rotterdam, Dresden, LSE, Bank of England, Bruges, Vancouver, British Academy.

2001: Edinburgh, LSE, Copenhagen, Durham, Madrid, UBS Warburg.

T. Börgers

1995: Indian Statistical Institute, Indira Gandhi Institute of Development Research.

1996: Cambridge (discussant of Churchill Lectures), Milan (IGIER Workshop on Economic Theory), Stony Brook (Social Learning Workshop), Tel Aviv ("Summer in Tel Aviv") Exeter, York, St Andrews, Texas A&M, Bangalore (International Conference on Game Theory), European University Institute.

1997: Birmingham (Royal Economic Society Easter School), Toulouse (discussant of plenary lecture on evolutionary game theory), Milan (IGIER Colloquium on Economic Research), Gerzensee (CEPR Summer Workshop on Economic Theory), Rotterdam, Manchester, Alicante.

1998: Yale, Princeton, Maryland, Pennsylvania, Pennsylvania State University, Magdeburg (Invited Lecture at the Society for Operations Research)

1999: Tilburg (Invited Talk at the 10th anniversary symposium of CENTER), Jena, Berlin, Magdeburg.

2000: Tilburg, Dortmund, Royal Holloway College, Harvard/MIT.

2001: Essex, Northwestern, Mannheim, Copenhagen, Lausanne (European Economic Association), Cornell, Oxford, Munich, Brussels (Auction Workshop), Munich (CES/Ifo Workshop on Telecommunications), Barcelona (Invited Talk at Workshop on Economic Design), London Business School.

2002: Radiocommunications Agency, Newcastle (Invited Talk to the Scotland-Newcastle Economic Theory Group), Tucson, British Columbia, Alicante.

T. Curzon Price

1998: London Business School, Cambridge (Judge Institute of Management).

A. Daripa

1997: Bank of England (joint conference with Financial Services Authority).

1998: New York (Federal Reserve Bank of New York).

R. Dunbar

1995: Bangor, New York (Cold Spring Harbor Symposium), Leeds (British Association for the Advancement of Science), Port Sunlight (Unilever CREF Conference), London (Zoological Society of London), Manchester (ASAB Biology Teachers Symposium), Sheffield, London (2nd International Evolution of Language Conference), Bolton Institute, Liverpool, Sheffield.

1996: Louvain-la-Neuve (Fondacion Delwart), Totnes (6th Darlington Literary Festival), Edinburgh, Seewiesen, Goldsmiths College, Manchester, Imperial College London, Edinburgh (Monro Lecture), Science Museum London, Central Lancashire University, Vienna (Plenary Speaker at the International Society for Human Ethology), Liverpool, Birkenhead Rotary Club, National Museum Bonn.

1997: Oxford, New York (Invited Lecture at the Coldspring Harbour Symposium), London (Cardiac 97 Conference, National Heart and Lung Centre), Sussex (Keynote Speaker at the Artificial Life Symposium), Bristol (Hewlett Packard Research Laboratories), Cambridge, Bristol, Edinburgh, Manchester (Invited Lecture at the ASAB Teachers Conference), Edinburgh Science Festival, Guernsey (Royal Bank of Canada Lecture), Exeter, Bristol, Brighton (Public Lecture at the Artificial Life Conference), Brussels.

1998: Cardiff, Uppsala (Dr van Hofsten Memorial Lecture), Edinburgh (Royal Institute of Philosophy Conference on Naturalism, Evolution and Mind), Oxford, Reading, Liverpool (English Speaking Union), Cambridge (Cambridge Philosophical Society), Liverpool, Cambridge, Lancaster.

1999: Oxford, Staffordshire, Sussex, Göttingen, Citta di Castello, London (Primate Society Conference).

2000: Uppsala, Otago, London (Institute of Cognitive Neuroscience), London (Primate Society), Addis Abeba (Conference on Ethiopian Biodiversity), Reading, Paris (CNRS Cognitive Sciences Seminar), Imperial College, Paris (Symposium on the Evolution of Culture), London (Laboratory Animal Sciences Association).

2001: Liverpool (Association of Science Teachers Conference), Glasgow (British Association for the Advancement of Science), Stonybrook, Liverpool, London (Human Behaviour and Evolution Society), Perth (Public Lecture at the Institute of Advanced Studies), Perth (University of Western Australia).

2002: Nottingham.

L. Fiddick

2001: London (Human Behavior and Evolution Society), London (Judgment and Decision Making Group), London (Darwin Work in Progress Group), Sunderland, Glasgow, Amsterdam (Conference on Subjective Probability, Utility and Decision Making).

2002: Wolverhampton.

N. Harvey

1997: London (Invited Lecture at the IEEE Computing and Control Division Colloquium on Decision Making), Barbados (International Symposium on Forecasting), Philadelphia (Psychonomic Society), Leeds (Conference on Subjective Probability, Utility and Decision Making), Essex, Tbilisi.

1998: Dallas (Society for Judgment and Decision Making), London (British Psychological Society), Dallas (Brunswik Society), Essex, Zurich.

1999: Hawaii (International Conference on System Sciences), London, Greenwich (Invited Lecture at the British Psychological Society), Amsterdam (Workshop on Risk Decision Making), Oxford (Human Sciences Symposium), Tbilisi.

2000: London (ESRC Programme on Risk and Human Behaviour), Amsterdam (Netherlands Forum on Medical Decision Making), Durham (4th International Conference on Thinking), Lisbon (International Symposium on Forecasting), Leiden (Netherlands Forum for Medical Decision Making), Cambridge (Joint Meeting of Experimental Psychology Society and Canadian Society for Brain, Behaviour and Cognitive Science), Oxford (Conference on Health and Risk), Norwich (Society for Social Medicine), Berlin (Brunswik Society), Hertfordshire.

2001: New Orleans (Psychonomics Society), Amsterdam (Keynote address at 18th Conference on Subjective Probability, Utility and Decision Making), Sussex, Loughborough.

C. Heyes

1996: Madison (International Primatological Society).

1997: Vienna (Konrad Lorenz Institute), International Ethological Conference (Plenary Lecture), Budapest (Cognitive Ethology Workshop), Cambridge (Cambridge Philosophical Society), London (MRC Cognitive Development Unit), Cambridge (MRC Applied Psychology Unit), Cambridge, Bristol, Exeter, Liverpool, UC Davis, UC Los Angeles.

1998: Naples (Antou Dohrn Research Institute), Vienna (Konrad Lorenz Institute), Warwick, Durham, London City University.

1999: Edinburgh (AISB Symposium), Bangalore (Plenary Lecture, International Ethological Congress), London (Invited Lecture, Association for the Study of Animal Behaviour).

2000: London (Invited Lecture, International Conference on 'The Evolution of the Intelligent Mind').

2001: Sydney (Macquarie University), London (Institute of Cognitive Neuroscience), Cardiff, Canberra (International Workshop on Evolutionary Psychology), London (Joint workshop of Institute of Cognitive Neuroscience and Institute of Movement Neuroscience).

2002: Indiana University (guest lecturer).

S. Huck

2001: Essex, Oxford.

2002: Burg Warberg (NPOe Meeting), CERGE-EI Prague, FU Berlin, Nottingham, Venice (European Economic Association).

R. Jackson

1996: Vancouver (International Federation of Operational Research Societies Meeting), Lisbon (European Working Group, Operational Research Applied to Health Services).

1997: Barcelona (INFORMS Conference).

P. Jehiel

1998: MIT-Harvard, Chicago.

1999: Bruxelles (ENTER jamboree), Munich, CORE, Southampton, Essex, Tilburg, Gerzensee (CEPR conference), Paris.

2000: Princeton, Heidelberg, MIT-Harvard, University of Pennsylvania, Yale, Institute for Advanced Studies Princeton, New York University, Princeton Economics.

2001: AT&T Laboratories, University of Illinois, University of Wisconsin, University of Rochester, Northwestern University.

H. Joffe

2001: British Academy Symposium, Royal Free Hospital, Stirling University, Ecoles des Hautes Etudes en Sciences Sociales, Paris.

2002: University of Lisbon, Stirling (International Conference on Social Representations).

C. Leaver

2001: Cambridge, Stockholm (CEPR/SNS Public Policy Symposium), Lausanne (ESEM Conference), Bristol.

2002: Stockholm (CEPR/SITE Incentives and Beyond Conference), Birmingham (RES Easter School), Warwick (RES Conference), Rochester, UEA.

A. Matros

2001: Moscow, Stockholm School of Economics, Stockholm University, University of North Carolina

G. Miller

1996: Cape Cod (Simulation of Adaptive Behaviour IV Conference), University of Oxford, London (Third Conference on Thinking), Madison (Sixth International Primatological Congress) London (Ciba Foundation Symposium).

1997: Fiesole (Inaugural Conference on Biomusicology), Oxford, Edinburgh (British Psychological Society Annual Conference), Sussex (British Psychological Society Annual Conference on Social Psychology).

1998: Max Planck Institute for Human Development, Berlin, UC Davis (Human Behavior and Evolution Society annual conference), London (2nd International Conference on the Evolution of Language) Liverpool, Warwick.

1999: London (Novartis Foundation symposium), Max Planck Institute for Human Development, University of Reading, City University of New York.

2000: London (Novartis Foundation), U. North London, Hay-on-Wye Literary Festival, Squaw Valley (Gruter Institute conference on evolution and business), Cambridge (Biology in the Boardroom conference), London (Evolution and innateness conference), Amherst (Human Behavior and Evolution Society Conference).

2001: London (Human Behavior and Evolution Society annual conference), London Business School.

B. Newell

2001: Manchester (Experimental Psychology Society), London (Judgment and Decision Making Group), Orlando (Annual Meeting of the Society for Judgment and Decision Making).

2002: Leuven (Joint meeting of the Experimental Psychology Society and the Belgian Psychological Society), London (Judgment and Decision Making Group).

M. Osman

2000: Würzburg (Summer-school: The acquisition of behavioural competence), Durham (4th International Conference of Thinking and Reasoning), Groningen (3rd International Conference on Cognitive Modeling), University of Dundee.

2001: Valencia (Third International Conference on Memory), Virginia (24th Annual Meeting of the Cognitive Science Society), Leuven (Experimental Psychology Society).

M. Ottaviani

1997: Milan (11th Conference on Game Theory and Applications), Gerzensee (CEPR), Milan (IGIER Colloquium Economic Research), Pasadena (North American Econometric Society Summer Meeting), Warwick (Summer Research Workshop, Dynamic Games and their Economic Applications), Nuffield, University of Southampton.

1998: Jerusalem (Summer School), Milan (IGIER Colloquia in Economic Research), Chicago (Discussant of Patrick Bolton, American Economic Association Winter Meetings), Ecole Normale Supérieure, Paris, Université de Cergy-Pontoise, Paris, University of Bristol, Fourgeaud Seminar, Paris, Gargano (Conference organised by CNR), Tilburg, Nuffield, University of Bologna, University of Newcastle.

1999: University of Venice, Bocconi University, University of Birmingham, Financial Services Authority.

2000: Brussels, Columbia University, Boston (Econometric Society Winter Meetings), Seattle (Econometric Society World Congress), Gerzensee (CEPR Conference on Economic Theory), Princeton University, Université Catholique de Louvain, CORE, University of Surrey, University of Berlin, University of Pennsylvania, Royal Holloway, University of Southampton.

2001: Atlanta (American Economic Association), Erasmus University Rotterdam, European University Institute, Florence, London Business School, Mannheim University, Mannheim (ENTER Jamboree), University of Bonn, Bristol (ESRC-PIPPS conference) WZB Berlin.

H. Plotkin

1996: Madison (16th Annual Congress of the International Primatological Society), London (University of the Third Age).

1997: Edinburgh (Keynote Address to the Annual Conference of the British Psychological Society), Emory University.

1998: Winter Park (XV Winter Conference on Animal Learning and Behaviour), Emory University, University of Sussex, Milton Keynes (University of the third Age), Konrad Lorenz Institute, Attenberg.

1999: Edinburgh (Royal Institute of Philosophy conference on Naturalism, Evolution and Mind), London School of Economics, Amsterdam (The Inaugural Spinoza Lecture on Science and Society, The International Institute for Social History), Cambridge (Conference on Memes: Towards a Darwinian Science of Culture), Rolle (International Committee for the Red Cross workshop on Humans and Weapons) University of Reading, Winchester (British Psychological Society workshop).

2000: London (International Conference on The Evolution of the Intelligent Mind), Institute of Community Studies, Balliol College.

2001: London (Human Behaviour and Evolution Society annual conference), Nottingham (Open University Evolutionary Psychology Conference)

G. Pollock

1996: Tel Aviv ("Summer in Tel Aviv").

R. Salmon

2002: Monterey (2nd World Congress of Environmental and Resource Economists).

R. Seymour

1999: Canberra (Bureau of Resource Sciences), Melbourne (Conference on Complexity in Management), Bournemouth (RBBSRC workshop on Theoretical Biology).

D. Shanks

1996: Brussels (Invited presentation at the Annual Meeting of the Belgian Psychological Society), Malaga (Invited presentation at the 8th Congress of the Spanish Comparative Psychology Society), Warwick (Cognition Conference), Montreal (Invited presentation at the International Congress of Psychology), Brighton (British Psychological Society conference).

1997: SimCat, Edinburgh (British Psychological Society), London (Third International Conference on Thinking), Oxford (Experimental Psychology Society meeting), London (Experimental Psychology Society meeting), Philadelphia (Annual Meeting of the Psychonomic Society)

1998: London (Experimental Psychology Society meeting), Philipps-Universität Marburg (40th Tagung experimentell arbeitender Psychologen), University of Liege.

1999: Leipzig (41st Tagung experimentell arbeitender Psychologen), Durham (Experimental Psychology Society meeting), London (Experimental Psychology Society meeting), Le Lignely (Cue Competition in Associative Learning conference), Providence (Invited presentation at the Annual Meeting of the Eastern Psychological Association), London (British Neuropsychological Society meeting).

2000: Durham (Fourth International Conference on Thinking), London (Experimental Psychology Society meeting), Gregynog (Associative Learning Symposium), Cambridge (Experimental Psychology Society meeting), Würzburg (Invited tutorial lecture at the ESCOP Summer School on the Acquisition of Behavioural Competence).

2001: Amsterdam (18th Bi-annual Conference on Subjective Probability, Utility and Decision Making), Gregynog (Associative Learning Symposium), Magnetic Island (Australian Learning Group Conference), Bristol (Experimental Psychology Society meeting).

J. Swierzbinski

1998: World Congress of Environmental and Resource Economists, European Association of Environmental and Resource Economists.

2001: European Association of Environmental and Resource Economists.

S. Talwar

1997: Stony Brook.

T. Troeger

2000: Bilbao (First World Conference of the Game Theory Society).

R. Tunney

2000: Essex (British Psychological Society), Durham (Fourth International Conference on Thinking).

D. Ulph

1996: Gregynog (Annual Conference of University of Wales), Strasbourg (Economics and Econometrics of Innovation conference) University of Mannheim, Athens, London (Invited speaker Launch of UNIDO Report on Globalisation), San Francisco (American Economic Association), University of Nantes.

1997: University of York, University of Kent, University of Laval, University of Bristol, University of Nantes, New Orleans (American Economic Association), Venice (Conference on Economic and Legal Aspects of Voluntary Agreements) Toulouse European Economic Association Conference), Crete (Keynote Speaker at Conference on Innovation, Competition and Employment).

1998: University of Paris I, University of Nantes, University of Aarhus, University of Tilburg, Bergen (Conference Labour and Product Markets in Open Economies), Copenhagen (European Association of Industrial Economists Meeting).

1999: Brussels (International Conference on Innovation), DTI, Sussex (International Workshop on Innovation and Research Joint Ventures), Turin (European Association for Research in Industrial Economics Meeting), London (CEPR Workshop), Athens, Cyprus, University of Crete, Milan (Joint FEEM/NBER Conference), Mannheim (International Workshop on Growth Inequality and Training).

2000: Bristol (Workshop on Public-Private Partnerships), Montreal (Conference on Super-Modularity and Innovation), Lausanne (EARIE meeting), Paris (GRIT Workshops), Crete ((GRIT Workshops), Marseille, Ancona, Boston, Berlin, Bocconi, Brussels (IPTS Meeting), Paris (CEP Conference), Paris (Conference on Technological policy and innovation, Economic and Historical Perspectives, organised by EUREqa-CNRS, OECD, CREST INSEE, Commisariat General du Plan Location).

2001: London (Conference, Network Learning), University of Madrid, Institute for Prospective Technologies, Financial Services Authority, Rotterdam.

R. Vaughan

1995: Tokyo (Econometric Society, 7th World Congress), London (ESRC Beliefs and Behaviour Programme, joint presentation with K Binmore).

1996: London (Office of Fair Trading), London (ESRC Seminar on Evolutionary Economics).

1999: University of Barcelona.

2000: Bilbao (First World Congress of Game Theory Society), London (Office of Fair Trading).

2001: London (NERA, joint presentation with J.Swierzbinski).

G. von Graevenitz

1999: Turin (European Association for Research in Industrial Organization)

2000: Montreal (Conference on Innovation and Supermodularity).

2001: Lausanne (European Meeting of the Econometric Society), Dublin (European Association for Research in Industrial Organization)

2002: Warwick (Royal Economic Society), Madrid (European Association for Research in Industrial Organization), Bristol (Centre for Market and Public Organisation)

N. Vulkan

1997: New Brunswick (DIMACS Conference), Rutgers University, Trinity College, Dublin.

1998: Tel Aviv University, Technical University, Haifa, Royal Holloway.

1999: Tel Aviv University.

10. Media Coverage

(a) Radio and Television Broadcasts

Binmore, K.

1996: Living Apart, BBC Radio 4, Analysis, February and March; TV interviews for Channel 4, Sky, CNN and Danish news channel; radio interviews for BBC Radio 4 (Science Programme and World at One).

2000: Interview, BBC Radio 4, The World Tonight, November.

2002: Interview, Newsnight, BBC 2, July.

Dunbar, R. I. M.

1995: extensive coverage of research by Kelly and Dunbar on both UK and international radio; interview, Swedish National Radio, November; interview for BBC Radio Devon; expert witness, Great Ape Trial, Channel 4, December.

1996: discussion on Woman's Hour, BBC Radio 4; interviewed twice BBC Radio Scotland; discussion BBC Radio North.

1997: interviews on "Science Now", BBC Radio 4; interviewed twice for BBC Radio 5; interviews for, Swedish National Radio, South African Radio, Radio Wisconsin, Radio Eireann, Radio Auckland, London Talk Radio, Greater London Radio, BBC Radio Guernsey, BBC Radio Devon, BBC Radio Derby, BBC Radio Belfast, Austrian Radio; discussions, BBC World Service and ABC Radio, Sydney; contributor to 3 part documentary series, BBC Radio 4.

2001: contributor, Discovery Channel programme; contributor, series on human evolution, WGBH TV series, Boston.

Heyes, C.

1995: Minds of Chimpanzees, Absolutely Animals, Channel 4, October; Animal Thoughts, Equinox documentary, Channel 4, December; Intelligence of great apes, The Great Ape Trial, Wall to Wall, Channel 4, December.

1996: Women in Science. Diverse documentary production for Channel 4, June; Sex and the Scientists, Diverse Production, Channel 4, August.

1998: Animal Consciousness, Green Umbrella production for Channel 4, January.

1999: Animal and computer intelligence. The Material World, BBC Radio 4, January; Animal intelligence, Do Elephants Weep?, BBC Radio 4, September; Animal

Language, All in the Mind, BBC Radio 4, September; Animal cognition, Inside the Animal Mind, PBS, USA, December.

2000: Insight Learning in Animals, Do animals think?, BBC Knowledge, September; interviewed about animal consciousness for a Channel 4 Science Documentary on animal mentality.

2001: Deception in animals. "Telling Lies", BBC for The Learning Channel, January.

Miller, G.

1997: South African National Radio Talk Show; live talk show, BBC Radio 5; interviews for BBC world service and BBC Radio 4, July; panel discussion on 'A question of science', BBC World Service, July.

1998: co-developer in summer of two television proposals that have been commissioned as Channel 4 "Equinox" films; one on the genetics and psychology of human happiness, and one on the evolution and genetics of psychopathy; contributor to BBC Radio 4-part series "Call of the Wild", about the evolution of acoustic signals in animals and humans, Spring.

2000: appearances on: Nightwaves, BBC Radio 3: a weekly science feature, BBC World Service; Start the Week, BBC Radio 4; Brian Morton Show, BBC Radio Scotland; 'Language of love' series, BBC World Service; a series on physical attractiveness, the Learning Channel; a series on evolution and ethnic differences, Channel 4; a 'Q & A' program for live half-hour interview, CNN; 'Esther' chat show, BBC2; a permanent video exhibition on Nature/Nurture at 'The Life Centre' museum, Newcastle; "Tomorrow's World" 'Megalab' special, BBC1; about 20 radio interviews for US stations (and syndicated networks) during book promotion tour for "The Mating Mind", May.

2001: appeared on a series 'The science of seduction', Discovery channel, Spring; filmed for a US series on evolution, PBS, Autumn.

Plotkin, H.

1997: New Ideas in the Social Sciences, Norwegian TV.

Tunney, R.

2001: the Edge, London, BBC.

(b) Newspaper Coverage

Binmore, K.

1996: The Independent, 7 October.

1998-99: More than 300 articles on auctions for licences to provide mobile phone services appeared in various leading newspapers in the UK and abroad.

2001: Time Finance, April; Singapore Business Times, July.

Börgers, T.

2001: Financial Times, December.

Dunbar, R. I. M.

1996: coverage in: Glasgow Herald, April; Canberra Times, May; Der Spiegel, May; Scientific American, November.

1997: coverage in: National Geographic Magazine, February; Lingua Franca (USA), March; The Times, May; Newsday (USA), May; Evening News (Guernsey), May; Chronicle of Higher Education (USA), May.

Leaver, C.

2002: Guardian.

Miller, G.

1996: coverage in The Daily Mail, The Observer and The Independent, November.

1997: Reinstating the beast in man, profile by Christian Tyler, Weekend Financial Times, January.

2000: 'The mating mind' was reviewed or featured in: Nature, New Scientist, The Financial Times, The Times, The Guardian, between April and August.

Ulph, D.

2000: Substantial media coverage regarding report on Contract Design and the Public Private Partnership for the London Underground. (D. Ulph and R. Vaughan); Coverage in most national newspapers, and referred to on national and local news television programmes. Most detailed coverage in Guardian. September.

11. Research Facilities

The ELSE Centre has two experimental laboratories, one based in the Economics Department and one in the Psychology Department.

The larger of the two laboratories, opened in September 2001, was established with the aid of a Joint Infrastructure Fund grant from ESRC and is based in the Economics Department (at Drayton House). The laboratory houses 28 networked personal computers with flat screen monitors. The room was designed to be reconfigurable so that it may be used both for experimentation and to deliver courses. Each computer and monitor is housed on its own desk as a separate unit so that it may be easily moved to a new location in the room. To aid the delivery of courses and research findings the room contains two projectors, a sound system and an interactive smart board along with an integrated control system. Privacy for experimental subjects is achieved by the use of removable partitions. An adjoining room contains the file server for the network and a network printer resides in the laboratory.

The second laboratory that has been in use throughout the Centre's history is situated in the Psychology Department (at Bedford Way). This laboratory contains twelve individual cubicles, each housing a personal computer and monitor that is part of a peer-to-peer network. The PCs in this laboratory were renewed early in 2002. A very wide range of experiments have been conducted in the Bedford Way laboratory, including studies by Binmore, Curzon-Price, McCarthy, Swierzbinski and Tomlinson evaluating auction formats (see Project 4.6 in Appendix A), by Heyes and Ray on imitation learning (Project 2.7), by Shanks and Tunney on decision making (Projects 2.3 and 2.5), and by Dunbar and Plotkin on inclusive fitness (Project 1.5).

The foundation of the new laboratory at Drayton House has enabled ELSE to extend its interdisciplinary work, both fundamental and applied, particularly in the areas of evolutionary approaches to bargaining theory and fairness norms, learning approaches to choice under risk and causal judgement, and in mechanism design, auctions with resale, complex multi-unit auctions and Ausubel auctions.

To date three series of experiments have been running in the laboratory with a total of over 350 unique subject visits being recorded. The inaugural experiments are part of a new project by Huck (ELSE), Hwang (Harvard), and Tomlinson (ELSE) on coordination in the presence of sunspots. The second series by Huck and Jehiel (ELSE) aims at testing Jehiel's analogy-based equilibrium notion (see Project 2.4 in Appendix A). The third series is joint work by Binmore, Swierzbinski and Tomlinson (all ELSE) who test the Rubinstein Bargaining Model (see also Binmore and others' related theoretical work in Appendix A, project 1.3.)

ELSE draws its subjects from a pool of over 1100 people. Subjects can join or leave the subject pool via a web interface on the ELSE website. The subjects invited to attend experiments can be filtered for particular characteristics if necessary.

These facilities also support the development of ELSE's programme of training and dissemination of ideas to the academic and user communities. The laboratory at

Drayton House has been used on numerous occasions to give visitors and researchers from other institutions demonstrations of our experiments and of our experimental software.

12. Consultancy Projects

(a) Advice on Spectrum Auctions

In the years 1999-2002 many countries around the world have issued licenses to operate third generation (3G) mobile telephone networks. These licenses allow companies to use certain identified parts of the radio spectrum for their operations. Many countries have adopted auctions as the primary means by which to determine which companies should get licenses. The economic theory of auctions is an application of the theory of games with incomplete information. As game theory is one of ELSE's areas of expertise, it seemed natural that ELSE should become involved with these auctions. In this subsection we report on our work in this area.

The wave of auctions for third generation mobile telephony licenses followed a sequence of very prominent auctions in the United States, which concerned second generation mobile telephones. These auctions were conducted by the United States' Federal Communications Commissions (FCC) from 1995 onwards. Several game theorists advised the FCC and bidders in these license auctions, including Paul Milgrom, Robert Wilson, and Preston McAfee. By getting involved in the 3G auctions we thus followed these researchers' example.

The increased use of auctions for the sale of government assets is a very important policy development worldwide. Spectrum auctions are just one element in that policy development. By advising on spectrum auctions ELSE has thus been part of an important long-term policy development.

Project 1: Advice to the UK's Radiocommunications Agency

Researchers: Binmore, Börgers, Jehiel, Miller, and Swierzbinski; also: Bulow (Stanford) and Klemperer (Oxford).

Duration: 1997-2000.

Description: The Radiocommunications Agency tendered for advice on this auction in 1997. ELSE won this competitive tender. In order to raise our expertise in the area of auction theory we brought in Paul Klemperer from the University of Oxford, who is probably the leading auction theorist in the UK. We also brought in Jeremy Bulow from Stanford who had extensive US experience, and who is a regular collaborator of Klemperer.

From 1997 onwards until the completion of the auction in 2002, ELSE's advice team, lead by Ken Binmore and Paul Klemperer, was involved in detailed meetings with the Radiocommunications Agency (RA) and with representatives from the interested industry about the auction design. ELSE produced several documents for the RA in which alternative auction designs were listed, and their advantages and disadvantages

were discussed. The RA also commissioned experiments from ELSE the purpose of which was to test the designs under discussion.

The UK government were strongly and publicly committed to allocational efficiency as the main goal of the UK auction. This required both that the auction allocated the licenses to the right bidders, but also that a sufficient number and quality of bidders was attracted to the auction. This participation consideration was a major concern during the preparation of the auction.

Two phases of the preparation of the UK auction can be distinguished. In the first phase, which lasted roughly until the autumn of 1998, it was anticipated that the number of technically feasible licenses was four. From the autumn of 1998 onwards, it was expected that this number was five. This was a very important point because the number of incumbent operators of second-generation mobile telephone services in the UK is four. Therefore, as long as only four third generation licenses were anticipated, the danger was that it was regarded as natural by the industry that only the incumbents would obtain new licenses, and that therefore participation in the auction would be very low. This danger was much less prominent once five licenses were deemed feasible.

To address the participation concerns in the case that only four licenses were available ELSE advisors advocated various versions of “Anglo-Dutch” auctions. These auctions, originally proposed by Klemperer, combine a first stage in which an open, ascending auction is conducted with a final sealed bid stage. The open ascending auction is suitable for achieving allocational efficiency, given the set of bidders present in the auction, and the added sealed bid stage is intended to make participation for outsiders attractive. ELSE wrote several memoranda regarding Anglo-Dutch auctions, and also conducted experiments to test various designs. The details of this work are still confidential.

Once it became clear that five licenses would be available, the participation concerns became less prominent, and ELSE recommended a straightforward open ascending auction. The design which ELSE proposed and which was eventually adopted is an adaptation of the auction designs used by the FCC in its license auctions in the mid 1990s.

The Radiocommunications Agency sold five licenses, labeled A, B, C, D and E. License A consisted of 15+15 MHz of paired spectrum and 5 MHz of unpaired spectrum. License B consisted of 15+15 MHz of paired spectrum. Licenses C, D and E consisted of 10+10 MHz of paired spectrum and 5 MHz of unpaired spectrum. Paired spectrum can be used more efficiently by third generation technology than unpaired spectrum. The licenses are to remain in force until 2021. The licenses came with an obligation to roll out a network covering at least 80% of the UK population by 2007. License A was reserved for a new entrant into the UK's mobile phone market. The incumbent four mobile telephone operators of the UK were not allowed to bid for this license.

The auction was organized in “rounds”. In each round of the auction except the first round each license had a “current price” and a “current price bidder”. In each round the current price bidders had to remain inactive. All other bidders had three actions

available to them. (1) They could place a bid for one of the licenses. This bid had to exceed the “current price” by a minimum increment that was announced by the Radiocommunications Agency before the round began. (2) They could ask for a “waiver”, i.e. do nothing. Each bidder could ask for a total of three waivers only in the auction. (3) They could withdraw from the auction. Withdrawal was final: a bidder who withdrew could not re-enter the auction.

The highest bid for each license became the “current price” in the next round, and the bidder who placed that bid became the “current price bidder” in the next round. If no bid was placed on a license then the “current price” and the “current price bidder” remained unchanged. If several bidders placed identical highest bids on a license then the “current price bidder” was randomly selected from these bidders. The auction ended when the last bidder who was not “current price bidder” for some license had withdrawn. Each “current price bidder” was then awarded their license at the “current bid”.

The four incumbent mobile telephone operators in the United Kingdom were: Vodafone, Cellnet (owned by British Telecom), Orange, and One2One. The four incumbents entered the auction. In addition, nine outsiders joined the auction. NTL Mobile, 3G UK, Worldcom, TIW, Telefonica, Spectrumco, Crescent, One.Tel, and Epsilon. The government agreed to regard these companies as independent bidders. Orange was owned by Mannesmann who, in turn, had just been taken over by Vodafone, but Vodafone had given an undertaking to the government to dispose of Orange after the auction, and to take measures which ensured the independence of Orange's bidding in the auction. ELSE advised on the question whether Vodafone and Orange should be allowed to bid as separate bidders.

The auction opened on 6 March 2000 and closed on 27 April 2000. The number of rounds was 150. All four incumbents won licenses. Vodafone won the large license B. License A, reserved for an outsider, was one by TIW. The TIW subsidiary that owned the license was later taken over by Hutchison 3G.

The prices paid by the winning bidders were very substantial. The three smaller licenses C, D and E all sold for around £ 4 billion. The larger license B sold for almost 6 £. The price of license A was approximately £ 4.4 billion. The total revenue to the UK government was about £22.5 billion. This was much more than the government had expected. The government was very satisfied with the outcome. The auction was very positively reviewed by the UK's National Audit Office. The UK auction raised larger revenues per head of the population than any other 3G auctions since.

Immediately after the auction there were some critical comments that suggested that the large prices paid would either result in lower quality services for customers or in higher prices. ELSE has argued against this, citing the economic theory of sunk costs, which suggests that future activities of the relevant telecommunications companies should only depend on their future financial incentives, not on fixed amounts paid in the past.

Since this auction took place the telecommunication industry's view of the potential profitability of 3G mobile telephone services has changed substantially, and it is now

widely argued that the prices paid for 3G licenses were higher than the business prospects in this sector really justify. However, this is clearly an ex post consideration, and the bids in the auction had to be based on the information available at the time.

Did the bids at the time reflect the companies' genuine assessment of the business case? We have undertaken detailed empirical evaluation of the auction data, and some ELSE researchers have argued that the available evidence is somewhat paradoxical, and that it is not clear that companies based their bids on well-defined business cases. The available evidence is slim, and no conclusive judgment can be reached regarding this issue. However, we emphasize that we regard the UK auction as a learning experience, and that it is more important to us to ask which lessons can be drawn from this auction, than to argue that the auction and its outcome should be viewed positively in every respect.

Project 2: Advice to the Government of Belgium

Researchers: Binmore

Duration: 2000

Description: In collaboration with Rothschild's Bank, we advised the Belgian government on its sale of 3G licenses. Their situation was similar to that of the UK - one more license than incumbent. We therefore proposed a similar design, which was used in practice. But the timing was very bad, as the NASDAQ had recently collapsed, and only three of four licenses were sold (at their reservation prices).

Project 3: Advice to the Government of Greece

Researchers: Binmore

Duration: 2000

Description: We did extensive work for the Greek government in association with KPMG. Our first task was to design two broadband auctions, which we chose to run simultaneously. This pair of auctions was regarded as a major success - one Greek newspaper said that it was the first occasion on which the Greek government had done anything that was not corrupt. The next project was to design their 3G auction, after which we organized another sale of further 2G spectrum. Although the Greek government did not make much money from any of these auctions, the Greek regulation authority has apparently gained much prestige from its good organization in these matters.

Project 4: Advice to the Government of Israel

Researchers: Binmore and Swierzbinski

Duration: 2000

Description: We worked directly for the Israeli telecom regulator giving policy advice on a similar range of telecom sales as the Greek. However, the regulator handled the detailed organization himself. (In Greece, we wrote the draft regulations in detail.) The civil troubles in Israel delayed and hindered the auctioning process, but events turned out surprisingly well in the circumstances.

Project 5: Advice to the Government of Denmark

Researchers: Binmore and Swierzbinski

Duration: 2001

Description: We designed the Danish 3G auction in association with Rothschild's Bank. Our judgment was that this was the most adverse situation we had faced - even worse than in Belgium, because the Danes had only four licenses to sell and four incumbents already operating in the industry. So the question arose who the new bidders were going to be. Following Paul Klemperer's suggestion already cited in our discussion of the UK situation, we argued that sealed-bid auctions could encourage entry in such hostile situations. The Danish government took our advice on this subject, and the outcome was probably favorable, both for our design and for the Danish government. A new bidder entered the auction and actually displaced one of the incumbents. Whereas the licenses were expected to go for their reservation price, they went for a respectable amount more.

Project 6: Advice to the Government of Hong Kong

Researchers: Binmore

Duration: 2000

Description: We advised the Hong Kong government on their 3G auction in association with Rothschild's Bank. Their problem was very difficult. The government had committed itself to an unprecedented auction in royalties, rather than in cash. But if the royalties bid got too large, it could distort the industry badly. We persuaded the Hong Kong authorities to include a cash payment as well, on a sliding scale that made the cash to be paid increase faster than the royalty bid. We also persuaded them to run a sealed-bid, lowest-winner auction - to promote entry and to ensure that all winners paid the same royalty rate. However, the incumbents persuaded the government to switch to a highest-loser (Vickrey) auction, which

removed the entry incentive. In the event, only the four major incumbents entered and so each was awarded one of the four licenses at the reservation royalty.

Project 7: Advice to the Dutch Parliament

Researchers: Börgers

Duration: 2001

Description: The Dutch parliament commissioned a review of the controversial third generation spectrum auction in the Netherlands. The contract for this review was won by a team from the University of Rotterdam, and Tilman Börgers acted as one of the three foreign advisors to this review. The other foreign advisors were Klemperer (Oxford) and Newbery (Cambridge). The review was completed with a very detailed report about the preparation and the conduct of the Dutch auction that was critical of many aspects of government policy.

Project 8 Advice to the Government of Latvia

Researchers: Börgers

Duration: 2002

Description: In association with the consulting company NERA we are advising the Latvian government regarding the auction of 3G spectrum licenses. This auction will take place in a more difficult environment than any of the previous auctions on which we have advised, partially because of local circumstances, and partially because of the changed climate in the telecommunications industry. It is planned that licenses will be sold using an ascending “clock” auction. At the time at which this report is written the auction has not yet taken place.

(b) Advice on Auctions in the Energy Sector

Auctions are increasingly used in the energy sector. Following ELSE’s work on spectrum auctions, our advice was sought both by regulators of the energy industry and by companies in this sector. In this subsection we report on the projects that we have undertaken in this area.

Project 9: Advice to BG Gas Storage

Researchers: Binmore and Curzon-Price

Duration: 1997-1999

Description: We advised British Gas Storage in a dispute with the gas regulator, who claimed that BG Storage was abusing its position as a natural monopolist, in that it owns the only large-scale storage facilities for gas in the UK (a depleted gas field called Rough off the coast of East Anglia). The proposed remedy was that storage services should be sold by auction with a zero reservation price. We argued that the industry should be seen as a bilateral monopoly with a competitive fringe on the buying side. The consequence is that making BG Storage sell with a zero reservation price would transfer all market power to the major buyer, Centrica. We also advised BG Storage that running an auction made good sense, provided that the reservation price was not too low. This advice was accepted.

Project 10: Advice to Transco

Researchers: Binmore, Curzon-Price and Vaughan

Duration: 1999

Description: Transco controls the national gas pipeline system in the United Kingdom. We worked extensively for Transco on the issue of pricing landing rights for North Sea gas. We designed a sophisticated auction that would have sold landing rights simultaneously at all landing sites. We also carried out a long series of laboratory studies comparing different types of auction. However, a more simple auction design was adopted.

Project 11: Advice to Ofgem

Researchers: Börgers

Duration: 2002

Description: Transco is preparing auctions of long-term entry capacity rights for the UK gas pipeline system. The regulator of the gas industry, Ofgem, asked us to comment on the auction design that Transco proposed. We offered a variety of comments that were then discussed with Transco. These auctions will begin in the fall of 2002, and we expect to be involved in the monitoring of the auctions and in potential reviews of the current auction design.

Project 12: Advice to the Australian National Grid

Researchers: Binmore, and Curzon-Price

Duration: 1997

Description: The electricity connectors between New South Wales and Victoria are a bottleneck that causes prices to differ in the two states. As a consequence, the grid company was accumulating a surplus that the Australian government insisted be dispersed to the consumer. IT was proposed to sell futures in the prices as hedging instruments. We agreed that the idea was good, but argued that it would not be practical to sell the full range of instruments proposed. We also advised on the design of an auction for the sale.

(c) Advice on Auctions in Other Sectors

Project 13: Advice to the UK Treasury

Researchers: Agastya, Binmore, Börgers, Swierzbinski

Duration: 1996

Description: Before the Bank of England became independent, it managed the sale of government bonds. We advised on the planned use of auctions to sell index-linked bonds.

Project 14: Advice to the UK National Audit Office

Researchers: Binmore

Duration: 2000

Description: The Treasury sold a substantial fraction of Britain's gold reserves in a sequence of auctions. The National Audit Office asked us to participate in its investigation of the arrangements. We endorsed the general approach, but criticised the Treasury's interpretation of openness as requiring inflexibility (for example, in the timing of sales). The National Audit Office report made our contribution central to its findings.

Project 15: Advice to the Dutch Government

Researchers: Börgers and Swierzbinski

Duration: 2001-2002

Description: The Dutch government commissioned from a team of economists a report assessing the use of auction methods and of administrative methods (“beauty contests”) in allocating government assets and contracts. This team was lead by researchers at the University of Rotterdam. From ELSE, the team was joined by

Börger and Swierzbinski. The ELSE researchers contributed a report on the use of different auction formats in the sale of government bonds. Börger also contributed to a survey, joint with Maasland and Moldovanu, of the use of auctions in allocating 3G spectrum licenses.

(d) Advice on Competition Policy

Project 16: Advice to Airtours

Researchers: Binmore, Curzon Price, Hernando, Ottaviani and von Graevenitz

Duration: 2000

Description: Airtours and First Choice are one of the four major British package holiday companies. Airtours proposed to take over First Choice. The British Competition Commission found this acceptable, but not DG IV at the European Commission. We were brought on as advisers by the lawyers working for Airtours. We argued that DG IV were mistaken in claiming that implicit collusion would be a likely outcome of the merger. Indeed, the package holiday business is so risky, with unpredictable shifts in demand from one year to the next, that it would be very difficult to make any kind of collusion stick, let alone tacit collusion. We were unable to move DG IV from their position and the merger was prohibited. A European court recently overruled DG IV and found in Airtours' favour. This case has had important repercussions for the way in which DG IV applies the notion of "collective dominance" in merger cases.

Project 17: Advice to the Competition Commission

Researchers: Binmore

Duration: 2000

Description: Binmore appeared as a witness before the Competition Commission opposing the takeover of Manchester United football club by Rupert Murdoch's BSKyB. We used the toehold argument from asymmetric auction theory to argue that he would then have an unfair advantage when bidding in the auction to secure the next tranche of premier football league rights. The commission ruled against the takeover.

(e) Advice on Incentive Schemes

Project 18: Advice to the Department of Health

Researchers: Jackson

Duration: 1995

Description: This was a collaborative project between ELSE and the Clinical Operations Research Unit (CORU) at UCL. It was funded by the Department of Health. We constructed a model to demonstrate how the internal market might operate in a revised NHS. A model was developed and the outcomes of various assumptions about the operational rules made accessible on a PC.

Project 19: Advice to the Financial Services Authority

Researchers: Agastya, Binmore, de Garidel-Thoron and Ottaviani

Duration: 2000

Description: When the Financial Services Authority was set up, its officers were unsure about which of many potential abuses to tackle first. We were employed to survey and comment on the literature, with a view to identifying serious abuses on which the Authority could tackle on firm theoretical ground.

Project 20: Advice to the Department of Health

Researchers: Binmore and Ulph

Duration: 2001

Description: This project required us to model consumer choice between public and private health care with a view to finding incentives for senior medical personnel that would minimize waiting times for NHS patients. We produced what we believe is the first such model, and fitted it to the very sparse data available. Its immediate use was to evaluate four incentive schemes that the Minister was considering at the time. All four schemes would result in waiting times being lengthened in our model. In the event, one of them was adopted.

(f) Other Advisory Projects

Project 21: Advice to the Department of the Bureau of Rural Sciences of the Australian Government

Researchers: Binmore, Seymour, Swierzbinski, Ulph and Vaughan

Duration: 1999

Description: This was a project with a short life as a consequence of a change in the Australian government. We provided advice on negotiating with the Japanese on coal

contracts, and with Korea and Japan on managing stocks of the blue-fin tuna in the Indian Ocean.

Project 22: Advice to the Department of Trade and Industry

Researchers: Seymour and Thomas (UCL)

Duration: 1997

Description: The project consisted of two phases. First, the Defence Research Group at the University of York had been commissioned by the Department of Trade and Industry to obtain data on the supply chain involved in the construction of an armoured vehicle for the British Army (as well as for export). This they had done by means of a detailed questionnaire. However, no statistical analysis of the results had been commissioned or undertaken, and we were asked to write a report to assess the potential for such an analysis. Second, after presenting our report, the York group together with the DTI drew up a list of hypotheses to be investigated, and we undertook the hypothesis testing based on the questionnaire data.

Project 23: Advice to the Forestry Commission

Researchers: Binmore, Inderst and Lane

Duration: 2000

Description: Collusion between large sawmills is a major problem in the timber industry, both here and abroad. We advised the Forestry Commission to abandon the company that was managing its sales, and to switch to an electronically organized first-price sealed-bid auction. An appropriate reform is currently in hand.

Project 24: Advice to the Environment Agency

Researchers: Swierzbinski and Salmon

Duration: 2001-2002

Description: Researchers at ELSE have been commissioned by the Environment Agency to conduct research into design and implementation of economic instruments for environmental policy. The goal of this project is to provide an improved understanding of how the detailed design of policy instruments in environmental policy can be expected to affect the behaviour of individuals and firms. It is planned that in the first year of the project three papers will be written. The first will survey the theoretical literature on market power in environmental permit markets. The second paper will study an application to a particular environmental market, and the

third will provide a foundation for further work, including both empirical analysis and laboratory experiments.

Project 25: Advice to the Radiocommunications Agency

Researchers: Börgers and Larson

Duration: 2002

Description: This is a joint project with the consulting company NERA. We have been commissioned to create software that simulates the possible functioning of a market for spectrum licenses. We are considering simple economic models that relate different possible ways of organizing a market for spectrum licenses. An economic analysis of these models is then conducted, and a software implementation of the models is prepared. At the time at which this report is written the project is not yet complete. We regard this project as an entry point into a wider European debate about spectrum trading.

Project 26: Contributions to a Commission Investigating Possible Reforms of the National Health Service

Researchers: Binmore

Duration: 2000

Description: Ken Binmore was a member of a commission set up by the community health councils for England and Wales that was asked to deliver a wide-ranging report on possible reforms of the United Kingdom's "National Health Service". This commission was chaired by Will Hutton, a member of ELSE's advisory committee, and it delivered its report in April 2000.

13. Training Courses

- 1) Training Course on Auction Theory for Employees of the Radiocommunications Agency, taught by Ken Binmore and Thomas Tröger, autumn 2001.
- 2) Training Course on Auction Theory for Employees of the Radiocommunications Agency, taught by Ken Binmore, Tilman Börgers and Nathan Larson, autumn 2002.

13. Degrees or Other Honours

Ken Binmore

Fellow of the British Academy (1995), Commander of the British Empire (2001), Honorary Member of the American Academy of Arts and Sciences (2002).

Robin Dunbar

Fellow of the British Academy (1998).

Annex C: Resources

1. Staffing

KEY: EA = Evolutionary Approaches LA = Learning Approaches BE = Behavioral Economics
 MD = Mechanism Design AT = Automated Trading and Negotiation IO = Industrial Organisation

Name	Grade	Research Division	% FTE ¹	Start	Finish	Destination
Directors						
Ken Binmore	Scientific Director	EA/MD/AT	100	1997	2001	
Ken Binmore	Director	EA/MD/AT	100	1997	2001	
Tilman Börgers	Director	LA/MD	50	2001	2001	
Tilman Börgers	Director	LA/MD	100	2002		
Ray Jackson	Executive Director	MD	50	1995	1997	
Henry Plotkin	Deputy Scientific Director	EA	10	1995	1997	
Henry Plotkin	Scientific Director	EA	10	1997	2001	
Rob Seymour	Deputy Executive Director	EA	10	1997	2002	
David Shanks	Scientific Director	LA/BE	25	2001	2002	
David Shanks	Scientific Deputy Director	LA/BE	25	2002		
David Ulph	Executive Director	AT/IO	50	1997	2001	Inland Revenue – Director Analysis and Research

¹ FTE means “full time equivalent”. Thus, this column indicates the percentage of a full workload that a colleague has devoted to ELSE.

Richard Vaughan	Deputy Executive Director	EA/AT/IO	10	1995	1997	
Richard Vaughan	Executive Director	EA/AT/IO	50	2001	2002	
Richard Vaughan	Executive Deputy Director	EA/AT/IO	50	2002		
Research Fellows And Staff						
Murali Agastya	Research Fellow	MD	10	1995	1997	
Murali Agastya	Research Fellow	MD	35	1997	1998	
Murali Agastya	Research Fellow	MD	25	1998	2001	Economics, University of Sydney
Philippe Aghion	Research Fellow	IO	10	1997		
Gian Luigi Albano	Research Fellow	MD/IO	50	2000		
Ahmed Anwar	Senior Research Fellow	EA	100	1997	1998	Lecturer in Economics, University of Edinburgh
Ken Binmore	Research Fellow	EA/MD/AT	50	2001		
Tilman Börger	Research Fellow	LA/MD	10	1995	1997	
Tilman Börger	Research Fellow	LA/MD	50	1997	1998	
Tilman Börger	Research Fellow	LA/MD	50	1998	2001	Became Director
Martin Boeg	Research Assistant	BE	50	2001		
Tony Curzon-Price	Research Assistant	MD	100	1998	2000	Chief Executive Officer APD
Robin Dunbar	Research Fellow	EA	10	1995		
Lawrence Fiddick	Research Fellow	EA	100	2001	2002	Researcher, National Institute of Neurological Disorders and Stroke (National Institutes of Health) Bethesda, USA.
Antonio Guarino	Senior Research Fellow		100	2002		
Nigel Harvey	Research Fellow	LA/BE	10	1996		
Celia Heyes	Research Fellow	EA/LA	10	1995		
Steffen Huck	Research Fellow	LA/MD/BA	50	2002		
Philippe Jehiel	Research Fellow	MD	10	1997	1999	
Philippe Jehiel	Research Fellow	MD	50	1999		
Helene Joffe	Research Fellow	BE/AT	10	2001		

Nathan Larson	Research Assistant	MD	100	2001		
Clare Leaver	Research Assistant	MD	100	2001		
Chris Lowen	Research Assistant		100	1995	1997	
John Lycett	Research Assistant	EA	100	1997	1999	
Elaine Madsen	Research Assistant		25	2001	2001	
Sonia Malkani	Administrative Secretary		100	1999		
Alexander Matros	Research Fellow	EA/LA/MD /IO	100	2001		
John McCarthy	Research Assistant	LA/MD/EA	100	1998	1999	Computer Science, UCL
Geoffrey Miller	Senior Research Fellow	EA/LA	100	1996	2000	Visiting Professor, Department of Communication Studies, UCLA
Ben Newell	Research Fellow	BE/LA	10	2000		
Eric Onuoha	Technician (JIF)		100	2001		
Magda Osman	Experimentation Manager		100	2001		
Marco Ottaviani	Research Fellow	IO/LA	10	1996	1997	
Marco Ottoviani	Research Fellow	IO/LA	50	1997	2001	London Business School
Henry Plotkin	Research Fellow	EA	10	1995		
Elizabeth Ray	Research Assistant		100	1998	1999	Psychology, UCL
Greg Pollock	Research Fellow	EA	100	1996	1996	Researcher, University of Bonn
Giovanni Ponti	Research Assistant	MD	100	1996	1996	Visiting Researcher, University of California at Santa Barbara
Anna Saggerson	Research Assistant	LA	50	2001	2001	
Sandra Semple	Administrator		100	1995	2002	Retired
Rob Seymour	Research Fellow	EA	10	1995	1997	Became Deputy Executive Director
Rob Seymour	Research Fellow	EA	10	2002		
David Shanks	Research Fellow	LA/BE	10	1995	1997	
David Shanks	Research Fellow	LA/BE	35	1997	1998	
David Shanks	Research Fellow	LA/BE	25	1998	2001	Became Scientific Director
Fiona South	Research Assistant	LA		1998	1999	

Peter Sozou	Research Fellow		50	1996	1998	Research Fellow, School of Public Policy, UCL
Joe Swierzbinski	Research Fellow	EA/BE/MD	10	1995	1997	
Joe Swierzbinski	Research Fellow	EA/BE/MD	35	1997	1998	
Joe Swierzbinski	Research Fellow	EA/BE/MD	25	1998		
Sunil Talwar	Research Assistant	AT	10	1996	1996	Chief Technical Officer, APD
Chris Tomlinson	Technician		40	1997		
Thomas Troeger	Research Fellow	LA/EA	100	1999	2001	Assistant Professor, Economics, University of California at Santa Barbara
Richard Tunney	Experimentation Manager	LA/EA	100	1999	2001	
Richard Tunney	Research Fellow	LA/EA	100	2001	2002	Lecturer in Psychology, University of Keele
David Ulph	Research Fellow	AT/IO	10	1995	1997	Succeeded Ray Jackson as Executive Director
Richard Vaughan	Research Fellow	EA/AT/IO	50	1997	1998	
Richard Vaughan	Research Fellow	EA/AT/IO	20	1999	2001	Became Executive Director
Nir Vulkan	Research Assistant	AT	100	1997	2002	Lecturer in Economics, University of Bristol
Simon Zelinski	Technician		40	1995	1997	

2. Funding

Table 1. Sources of Funding 1995-2002

£'000

Funder	1995/96	1996/97	1997/98	1998/99	1999/2000	2000/01	2001/02	Type
ESRC	413	399	422	453	464	465	471	Core funding
University College London	250	248	212	260	236	269	280	Host funding
(a) UK Research Councils	63	105	49	180	182	274	163	Co-funding
(b) Other UK research bodies	65	65	65	90	89	235	159	Co-funding
(c) UK Government and Agencies	14	0	47	53	5	126	155	Co-funding
(d) UK Industry and Commerce	0	0	55	149	74	142	0	Co-funding
(e) European Community	49	34	140	161	147	74	29	Co-funding
(f) International Research Bodies			7	3			0	Co-funding
(g) International Government Agencies	0	0	0	0	0	38	0	Co-funding
Total	854	851	997	1,349	1,197	1,623	1,257	

Table 2. Detailed Sources of Co-Funding. 1995-2002

Funder	Amount	Dates	Holder	Topic
BBSRC	£126K	1995-1997	Heyes	Imitation
Leverhulme Foundation	£275	1995-2000	Binmore	Leverhulme Research Professorship
Royal Society	£30K	1995-1998	Dunbar	Mate choice & parental investment
Department of Health	£10K	1995-96	Jackson	Internal Market and the NHS
European Commission (DG-II)	£24K	1995-96	Ulph	Industrial Location, Employment and Economic Policy
Office of Fair Trading	£4K	1995-96	Vaughan	Welfare Assessment and Competition Policy
European Community (TMR)	£25K	1995-96	Ulph	Training and Mobility of Researchers
European Community (TSER)	£14K	1996-99	Ulph	Innovation, R&D and Productivity
European Community (TSER)	£378K	1996-2000	Ulph	Research Joint Ventures
ESRC	£124K	1996-1999	Harvey	Forecasting from time series data
ESRC	£15K	1997-99	Börgers	Game Theory
Radiocommunications Agency	£93K	1997-9	Binmore	Auction Design for the sale of licences for the 3G Mobile Phone Network
Unilever	£15K	1997	Dunbar	Grooming
BG Storage	£80K	1997-99	Binmore	Auction and Mechanism Design in relation to Gas Storage Facilities
Department of Trade and Industry	£7K	1998	Seymour	Statistical analysis of supply chains of the British Army
ESRC	£34K	1998-2000	Ulph	Economic Implications of Trading with Smart Agents
European Commission	£135K	1998-2001	Ulph	Growth, Inequality and Training (GRIT)
EPSRC	£106K	1998-2002	Binmore	Automated Negotiation and Smart Agents
Hewlett-Packard	£12K	1998	Dunbar	Network size
ESRC	£12K	1998	Ulph	User Application in relation to e-commerce

Unilever	£40K	1998-9	Heyes	Assessing an imitation test of 'refreshment'
BBSRC	£184K	1998-2001	Heyes	Social learning
ESRC	£126K	1998-2001	Shanks	Rule learning
BG Transco	£107K	1998-2000	Binmore	Entry Capacity Project
Leverhulme	£16K	1998-2000	Shanks	Implicit learning
Unilever	£6K	1998-2000	Heyes	Design of experiments to assess product categorisation by consumers.
ESRC	£13K	1999-2001	Börgers	Game Theory
Unilever	£18K	1999	Dunbar	Grooming
Financial Services Authority	£5K	1999-2000	Binmore	Agency Problems and the Regulation in the Retail Market for Financial Services
ESRC	£163K	1999-2002	Harvey	Judgement
Airtours	£3K	2000	Binmore	The Economics of Implicit Collusion
Cable and Wireless	£5K	2000	Binmore	Analysis of proposed takeover of MUFC by BSKyB
Forestry Commission	£46K	2000	Binmore	Auction design advice regarding timber sales
European Commission	£4K	2000-2001	Ulph	Price Transparency and the Single European Currency
Office of Fair Trading	£5K	2000	Vaughan	Welfare Assessment and Consumer Affairs Policy
National Audit Office	£9K	2000	Binmore	Examination of UK Sales of Gold Shares
Industrial Society	£9K	2000	Ulph	Public Private Partnership and the London Underground
Rothschilds	£14K	2000	Binmore	UMTS (Mobile Phone Licences) Auction Advice (Belgium)
KPMG (Greece)	£87K	2000	Binmore	Advice for the Greek Government's 2.5 and 3.5 GHz Auctions
Israeli Dept. of Communications	£38K	2000	Binmore	Israeli 3G Auction Advice
Rothschilds	£21K	2000	Binmore	Danish 3G Auction Advice
Rothschilds	£3K	2000	Binmore	Hong Kong 3G Auction Advice
HM Treasury	£10K	2000	Ulph	PFI Value for Money (Treasury Task Force)

European Community	£100K	2000-04	Ulph	Product Markets and the Pace of Innovation in Europe
Radiocommunications Agency	£56K	2000-	Binmore	28GHz Auction Design and follow-up
ESRC	£28K	2000	Ulph	European Network of Excellence project (ENCREE)
ESRC	£42K	2000-2001	Shanks	Implicit knowledge
ESRC	£40K	2000-2001	Shanks	Probability judgement
BBSRC	£117K	2000-2003	Shanks	Covariation Learning
Department of Health	£60K	2001	Ulph	Health Service Pay Structures
ESRC	£87K	2001-2004	Shanks	Optimality and insight
BBSRC	£157K	2001-2004	Shanks	Strategic processes
Leverhulme	£85K	2001-2004	Shanks	Optimality
Joint Infrastructure Fund	£815K	2001-2004	Ulph	Drayton House Laboratory and Computing Staff
European Commission	£10K	2001-2004	Ulph	ENGIME project
Environment Agency (UK)	£99K	2001-2004	Swierzbinski	Design and Implementation of New Environmental Policy Instruments
Russell Sage Foundation & University of St.Gallen	£62K	2001-2002	Huck	Trust and the Internet
ESRC	£30K	2002-2003	Leaver	Fellowship
ESRC	£29K	2002-2003	Von Graevenitz	Fellowship
Leverhulme	£96K	2002-2004	Huck	Social Learning

3. Facilities

Location

ELSE is situated in a recently refurbished building adjacent to UCL's main campus in central London, and is to be found on two floors of the Drayton House building of the University. The Centre shares the building with the Department of Economics. The top floor comprises office accommodation for research and support staff as well as for graduate students and visitors connected with the Centre. In addition there is a seminar and conference facility equipped with multimedia equipment as discussed below. The Laboratory facilities and offices for the computing staff are to be found on the first floor of the Building. Lecture theatres are available in the building for the case of larger meetings, as are lecture theatres on the main UCL campus.

Library Facilities

ELSE staff are able to use a wide range of facilities at UCL including the library containing over 1.5 million volumes. In addition the University of London Library at Senate House and the British Library are within walking distance of the Centre.

Experimental Laboratories

The ELSE Centre has two experimental laboratories, one based in the Economics Department and one in the Psychology Department.

The larger of the two laboratories is based in the Economics Department (at Drayton House) and houses 28 networked personal computers with flat screen monitors that were purchased in 2001. An adjoining room contains the file server for the network and a network printer resides in the laboratory. The room was designed to be reconfigurable so that it may be used both for experimentation and to deliver courses. Each computer and monitor is housed on its own desk as a separate unit so that it may be easily moved to a new location in the room. To aid the delivery of courses and research findings the room contains two projectors, a sound system and an interactive smart board along with an integrated control system. Privacy for experimental subjects is achieved by the use of removable partitions.

The second laboratory resides in the Psychology Department (at Bedford Way). This laboratory contains twelve individual cubicles, each housing a personal computer and monitor that is part of a peer-to-peer network. The PCs in this laboratory were renewed early in 2002.

Seminar Room

The ELSE Centre also has a separate seminar room in Drayton House in which meetings, seminars, discussions and interviews can take place. To enable computer

based demonstrations the room contains a sound-enabled PC and speakers, a projector, an interactive smart board and a visualiser. The visualiser can also be used in the large ELSE laboratory if necessary.

Staff Equipment

The Centre also provides computing equipment for staff and students who are members of the centre. This equipment is allocated according to need and is in a constant state of renewal. The centre owns approximately 30 desk-based personal computers, approximately 10 laptop computers and approximately 15 printers. The age and quality of this equipment varies from user to user with the oldest item being approximately five years old.

Maintenance

The Centre endeavours to maintain all of its directly owned computing and multimedia equipment through its computing staff.

College Computing Facilities

Members of the Centre are granted use of UCL computing facilities. This includes access to cluster rooms and library systems, use of the university network backbone, and use of the university's DNS servers and gateway. The university also administers staff email accounts. Several faculty members who are also in ELSE have use of a department owned and maintained personal computer.

Annex D: Advisory Committee

Membership of Centre Advisory Committee

Current members:

Mr Hans Liesner	Chair
Ms Heather Booth di Giovanni	Department of Trade and Industry
Mr Creon Butler	Foreign and Commonwealth Office
Professor Stephen Gallivan	Clinical Operational Research Unit, UCL
Mr Will Hutton	Industrial Society
Mr Anthony Lines	Consultant, Logistics
Ms Bridget Rosewell	Volterra Consulting
Professor Maurice Shutler	Operational Research, LSE

Former members:

Professor John Beath	Economics, University of St. Andrews
Mr James Hemsley	Chairman, Brameur Ltd
Ms Christine McCulloch	ESRC
Sir Michael Peckham	Head, School of Public Policy (UCL)
Dr Mohammed Quraishi	ESRC
Dr Geoffrey Royston	Head of Operational Research, NHS Executive Headquarters
Professor Peter Spencer	ESRC
Professor Phillip Treleaven	Computer Science Department (UCL)
Professor David Woods	ESRC

Annex E: Other Activities

1. Conferences and Seminars

1995-1996

1) ELSE organised a bi-weekly seminar series with the following speakers: (Speakers are associated with ELSE, unless otherwise indicated.)

Binmore, K., Evolutionary Ethics and Utilitarianism, October 1995.

Dunbar, R. and H. Plotkin, Some Evolutionary Features of Human Psychology, October 1995.

Dunbar, R. and C. Lowen, Modelling Cultural Evolution, November 1995.

Fischer, I. (UCL), The Evolution of Cooperation in Simulated Inter-Group Conflict, February 1996.

Holland, J. (Michigan), Hidden Order, January 1996.

Key, C. (UCL), The Prisoner's Dilemma in a Heterogeneous Environment, January 1996.

Laland, K. (Cambridge), Is Social Learning Always Adaptive?, May 1996.

Mace, R. (UCL), Where Do Preferences Come From? - The Case of Sex Preferences in Parental Investment, February 1996.

Mailath, G. (Pennsylvania), Your Reputation is Who You're Not, Not Who You Are, January 1996.

Miller, G. (Max Planck Institute Berlin), Mating Games, April 1996.

Penn, A. (UCL), Estimating Pedestrian Density from City Plans: Possible Applications to Site Valuation, June 1996.

Pollock, G. The Whores of Group Selection, March 1996.

Samuelson, L. (Wisconsin), Hard Bargains and Lost Opportunities, June 1996.

Shanks, D., Psychological Models of Choice, November 1995.

Sozou, P. and R. Chandler, A spatial statistical test for dependencies in data, April 1996.

Vaughan, R., On the Emergence of Collective Behaviour, December 1995.

2) ELSE provided financial support for the weekly economic theory seminar at UCL.

3) ELSE provided financial support for the Research Seminars in Evolutionary Psychology and Behavioural Ecology at the University of Liverpool. These seminars were organised by Robin Dunbar.

1996-1997

1) ELSE organised a series of occasional seminars with the following speakers:

Butler, C., (Bank of England), Selling Index-Linked Bonds and Other Central Bank Problems, March 1997.

Harbord, D. (David Harbord Associates), Pricing and Competition in Electricity Spot Markets, December 1996.

Holland, J. (University of Michigan), and H. Plotkin, Evolutionary Models in Artificial Intelligence: Are They Relevant to Human Learning?, March 1997

Kardes, F. (Northern Kentucky University), Consumer Decision Making, October 1996.

Plotkin, H., The Evolution of Language, April 1997.

Saari, D. (Northwestern University), From Arrow's and Sen's Theorems to the Spatial Voting Core, April 1997.

2) ELSE organised a conference on 'Risk and Decision Making' (December 1996). The speakers were: A. McClelland, F. Kardes, P. Ayton, J. Swierzbinski, F. Bolger, and D. Hardman.

3) ELSE organised a conference on 'Auctions and Government Policy' (December 1996). The speakers were: P. Cramton (Maryland), A. Daripa (Birkbeck College), P. Jehiel, P. Klemperer (Oxford), P. Mills (HM Treasury).

4) ELSE organised a half-day workshop on "honesty". The lead organiser of this workshop was Robin Dunbar.

5) ELSE organised a joint conference with the School of Public Policy at UCL on the 'NHS Internal Market' (March 1997).

6) ELSE provided financial support for the weekly economic theory seminar at UCL.

7) ELSE provided financial support for the Research Seminars in Evolutionary Psychology and Behavioural Ecology at the University of Liverpool. These seminars were organised by Robin Dunbar.

8) ELSE provided financial support for the 'ESRC Research Seminars in Economic Theory', jointly organized by M. Agastya, T. Börgers, and M. Cripps.

1997-1998

1) ELSE organised a conference on 'Corporate Governance in Eastern Europe' (October 1997).

2) ELSE organised a two day symposium on 'The Evolution of Utilities and Utility Functions: Biological Foundations of Economics' (December 1997). The speakers included: C. Bergstrom (Stanford), K. Binmore, J. Hey (York), G. Miller, R. Sethi (Columbia).

3) ELSE organised a conference on 'Competition and Innovation' (January 1998).

4) ELSE provided financial support for the weekly economic theory seminar at UCL.

5) ELSE provided financial support for the Research Seminars in Evolutionary Psychology and Behavioural Ecology at the University of Liverpool. These seminars were organised by Robin Dunbar.

6) ELSE provided financial support for the 'ESRC Research Seminars in Economic Theory', jointly organized by M. Agastya, T. Börgers, and M. Cripps.

1998-1999

1) ELSE organised a series of occasional seminars which included the following presentations:

- Binmore, K, Fairness: Theories and Possible Empirical Approaches.
- Börger T, Why Learning is Central to Economics.
- Dickinson A., Why Have Psychologists Abandoned Behaviourism?
- Dunbar, R. I. M., Behavioural Ecology Amongst the Social Sciences.
- Giraldeau, Luc-Alain, Paying Attention to Others: The Economics of Public Information in a Group Foraging Context.
- Harvey, N., Using Judgement to Make Inference From Time Series Data.
- Heyes, C., and E. Ray, Imitation.
- Jehiel, P., Limited Foresight in Games.
- Miller, G., Did Humans Evolve Any Heuristics for Solving Coordination Games?
- McCarthy, J., Understanding Things In Time.
- Plotkin, H., Where Evolutionary Psychology Has Come From, Where It Is, And Where It Is Going.
- Shanks, D., Matching and Maximizing in One-Person Games.
- Lunt, P., Reflections on The Relationship Between Psychology and Economics.
- Tomasello, M., The Human Adaptation for Culture.
- Young. P., (Johns Hopkins), Limits to Rationality: Possibility and Impossibility Results in Learning.
- 2) ELSE organised a seminar on ‘Growth, Inequality and Training’ (December 1998).
- 3) ELSE organised a seminar on ‘Automated Trading’. Speakers were Long J., (UCL) and D. Ulph.
- 4) ELSE provided financial support for the weekly economic theory seminar at UCL.
- 5) ELSE provided financial support for the Research Seminars in Evolutionary Psychology and Behavioural Ecology at the University of Liverpool. These seminars were organised by Robin Dunbar.

6) ELSE provided financial support for the 'ESRC Research Seminars in Economic Theory', jointly organized by M. Agastya, T. Börgers, and M. Cripps.

1999-2000

1) ELSE organised a sequence of occasional seminars. Presentations included:

Börgers, T., When Does Learning Lead to Nash Equilibrium?

Dunbar, R. I. M. and H. Plotkin, An Experimental Test of Hamilton's Rule.

Shanks, D., Melioration and Rational Choice.

Vaughan, R., Schelling the System: The Potential for Equilibrium Selection.

2) ELSE organised a workshop on 'Growth, Inequality and Training'.

3) ELSE organised a workshop on 'Innovation Systems'.

4) ELSE organised a joint workshop with the Centre for Ecology and Evolution on 'Signs of Quality: The Handicap Principle in Biology, Economics, and Culture' (December 1999).

5) ELSE provided financial support for the weekly economic theory seminar at UCL.

6) ELSE provided financial support for the Research Seminars in Evolutionary Psychology and Behavioural Ecology at the University of Liverpool. These seminars were organised by Robin Dunbar.

7) ELSE provided financial support for the 'ESRC Research Seminars in Economic Theory', jointly organized by M. Agastya, T. Börgers, and M. Cripps.

2000-2001

1) ELSE organised a seminar for employees of the consulting company NERA on 'Airport Slot Allocation Mechanisms'.

2) ELSE provided financial support for the weekly economic theory seminar at UCL.

3) ELSE provided financial support for the Research Seminars in Evolutionary Psychology and Behavioural Ecology at the University of Liverpool. These seminars were organised by Robin Dunbar.

4) ELSE provided financial support for the 'ESRC Research Seminars in Economic Theory', jointly organized by M. Agastya, T. Börgers, and M. Cripps.

2001-2002

1) ELSE organised a seminar on 'Quantitative Approaches to Learning Dynamics' with the following speakers (November 2001).

Engle-Warnick, J. (Nuffield College, Oxford), Inferring Repeated Game Strategies from Actions: Evidence from Trust Game Experiments.

Ichimura, H. (UCL), Identification Problems in Experience Weighted Attraction Learning Models and Their Empirical Implications.

Larson, N., Match Choice and Ghettoization in Evolutionary Games.

Shanks, D., Learning and Optimal Choice.

2) ELSE organised a workshop on 'Current Issues in the Psychology of Judgement and Decision Making' with the following speakers (January 2002).

Ayton, P. (City University), Probability Judgment and Cognitive Illusions.

Harvey, N., Experience, Feedback and Improvements in the Quality of Judgment and Decision-Making.

Newell, B., One-Reason Decision Making? Investigating the Fast and Frugal Approach.

Sevdalis, N. (UCL), Anticipated Emotional Reactions to Decision Outcomes: From Minimax Principle to Regret Theory and Beyond.

3) ELSE organised a workshop on 'Motivation and Incentives in the Workplace' with the following speakers (March 2002).

Eyster, E. (Nuffield College Oxford), A Preference for Consistency.

Huck, S., Engineering Trust.

Leaver, C., Public Service Motivation and Extrinsic Rewards.

Rey-Biel, P., Fairness, Reciprocity and Team Incentives.

4) ELSE organised a workshop on 'Industrial Organisation' with the following speakers (May 2002).

Hall, B. (Berkeley), Current Issues and Trends in the Economics of Patents.

Inderst, R. (LSE), Buyer Power.

Matros, A., Bertrand Competition with Intertemporal Demand.

von Graevenitz, G., Absorptive Capacity and RJV Formation.

5) ELSE provided financial support for the weekly economic theory seminar at UCL.

6) ELSE provided financial support for the Research Seminars in Evolutionary Psychology and Behavioural Ecology at the University of Liverpool. These seminars were organised by Robin Dunbar.

2. External Fellows of ELSE

The following are honorary external research fellows of ELSE:

- 1) Professor John Beath, Department of Economics, University of St Andrews
- 2) Professor Eddie Dekel, Department of Economics, Northwestern University, and Department of Economics, Tel Aviv University
- 3) Professor David Enacoua, Universite de Paris I
- 4) Professor Paul Klemperer, Nuffield College, Oxford University
- 5) Professor Larry Samuelson, Department of Economics, University of Wisconsin
- 6) Professor Jörgen Weibull, Department of Economics, Boston University
- 7) Professor Menahem Yaari, Department of Economics, Hebrew University Jerusalem

3. Visitors

1995-1996

Dr. Tomas Bereczkei	Medical University of Pecs, Hungary
Professor Ted Bergstrom	University of Michigan, USA
Dr. Antonio Cabrales	Pompeu Fabra, Barcelona, Spain
Professor Drew Fudenberg	Harvard University, USA
Dr. Frederic Gaspart	University of Namur, Belgium
Professor John Holland	Santa Fe Institute, New Mexico, USA
Professor Frank Kardes	Northern Kentucky University, USA
Dr. Kevin Leland	University of Oxford
Dr. John Lycett	University of Natal, South Africa
Professor George Mailath	University of Pennsylvania, USA
Professor Vassilis Moustakis	University of Crete, Greece
Professor Larry Samuelson	University of Wisconsin, USA
Dr. Rajiv Sarin	Texas A&M, USA
Professor Avner Shaked	University of Bonn, Germany

1996-1997

Dr. T. Bereczkei	Medical University of Pècs, Hungary
Professor Kalyan Chatterjee	Pennsylvania State University, USA
Professor Peter Cramton	University of Maryland, USA
Dr. Jean Czerlinski	Max Planck Institute for Psychological Research Berlin, Germany
Dr. Jennifer Davis	Max Planck Institute for Psychological Research Berlin, Germany
Dr. Uwe Dulleck	Humboldt University Berlin, Germany
Professor P. Henzi	University of Natal, South Africa
Professor Frank Kardes	University of Cincinnati, USA
Dr. Tim Ketelaar	Max Planck Institute for Psychological Research Berlin, Germany
Dr. Alejandro Lopez	Max Planck Institute for Psychological Research Berlin, Germany
Dr. J. Lycett	University of Natal, South Africa
Dr Francisco Maringelli	Centre for Economic Policy Research
Professor Guiseppe Moscarini	Yale University, USA
Professor Arthur Robson	University of Western Ontario, Canada
Professor Larry Samuelson	University of Wisconsin, USA
Professor Rajiv Sarin	Texas A and M University, USA
Dr. Peter Todd	Max Planck Institute for Psychological Research Berlin, Germany

1997-1998

Professor Larry Ausubel	University of Maryland, USA
Dr. Carl Bergstrom	Stanford University, California, USA
Professor Ted Bergstrom	University of Santa Barbara, California USA
Dr. Bernhard Borges	Coopers & Lybrand, New York USA
Professor Thomas Brenner	University of Jena, Germany
Dr. Seth Bullock	Max Plank Institute, Berlin, Germany
Professor Oliver Compte	CERAS, France
Professor Catherine Eckel	National Science Foundation, Washington DC, USA
Professor Martin Hellwig	University of Mannheim, Germany
Professor Yannis Katsoulacos	University of Athens, Greece
Professor Vijay Krishna	Pennstate University, USA
Professor Lola Lopes	University of Iowa, USA
Professor Dov Monderer	University of Haifa, Israel
Professor Rosemary Nagel	University of Pompeu Fabra, Barcelona, Spain
Professor Robert Owen	University of Nantes, France
Dr. B. Pawlowski	University of Wroclaw, Poland
Professor Arthur Robson	University of Western Ontario, Canada
Professor Paul Rubin Emory	University, Georgia, USA
Professor Larry Samuelson	University of Wisconsin, USA
Professor Rajiv Sethi	Columbia University, New York, USA
Dr. Tilman Slembeck	University of St Gallen, Switzerland
Dr. Peter Todd	Max Plank Institute, Berlin, Germany
Professor F. Vega-Redondo	University of Alicante, Spain
Professor Karl Wärneryd	Stockholm School of Economics, Sweden
Professor Jörgen Weibull	University of Stockholm, Sweden
Professor Frank Wolack	Stanford University, USA
Professor Menahem Yaari	Hebrew University Jerusalem, Israel
Professor Ehud Zuscovitch	Ben-Gurion University of Negev, Israel

1998-1999

Professor Alain Giraldeau	Princeton University, USA
Professor Yannis Katsoulacos	University of Athens, Greece
Professor Robert Owen	University of Paris, France
Professor Dov Samet	Tel Aviv University, Israel
Professor Michael Tomasello	Max Planck Institute Leipzig, Germany

1999-2000

Professor Masaki Aoyagi	University of Pittsburgh, USA
Professor Kalyan Chatterjee	The Pennsylvania University, USA
Professor Eddie Dekkel	Northwestern University, USA
Mr. Eric Dickson	University of Massachusetts Medical School, USA
Mr. David Encaoua	University of Paris, France
Mr. Alfonso Gambardella	University of Paris, France
Ms. Booth Giovanni	Department of Trade and Industry, UK
Dr. Ed Hopkins	University of Edinburgh, UK
Professor Morton Kamien	Northwestern University, USA
Professor Yannis Katsoulacos	University of Athens, Greece
Mr. German Loewe	University of Barcelona, Spain
Professor Roger Myerson	Northwestern University, USA
Professor Barry O'Neill	Stanford University, USA
Professor Robert Owen	University of Paris, France
Dr. Jens Tapking	University of Saarbrücken, Germany
Professor Menahem Yaari	Hebrew University, Jerusalem
Professor Ilan Yaniv	Hebrew University, Jerusalem
Mr. Peter Young	University of California, Santa Cruz, USA

2000-2001

Dr. Carlos Alos-Ferrer	LEGATE University of Vienna, Austria
Professor Andreas Blume	University of Pittsburg, USA
Professor Kalyan Chatterjee	University of Pennsylvania, USA
Professor Claude d'Aspremont	Universite Catholique de Louvain, Belgium
Professor Eric Damme	CentER for Economic Research, Tilburg Netherlands
Professor Patrick Francois	CentER for Economic Research, Tilburg Netherlands
Professor Gerd Gigerenzer	Center for Adaptive Behavior and Cognition Max Planck Institute, Berlin, Germany
Professor Peter Hammerstein	Humboldt University, Berlin Germany
Professor Ron Harstad	Rutgers University, USA
Professor Sergiu Hart	Hebrew University, Jerusalem, Israel
Dr Angel Hernando	University of Alicante, Spain
Professor Josef Hofbauer	University of Vienna, Austria
Professor John Kagel	Ohio State University, USA
Professor Guy Laroque	Paris, France
Professor Patrick Legros	ECARES, Universite Libre de Bruxelles
Professor Bart Lipman	University of Wisconsin, USA
Professor Jacques Mairesse	GCRECSTA, INSEE
Professor Kiminori Matsuyama	Northwestern University, USA
Professor John Nachbar	Washington University, USA

Professor Jan van Ours	Centre for Economic Research, Tilburg University, Netherlands
Professor David Perez-Castrillo	University Barcelona
Professor Philip Reny	University of Chicago, USA
Professor Lars Roller	Wissenschaftszentrum Berlin, Germany
Professor Ariel Rubinstein	University of Tel Aviv
Professor Larry Samuelson	University of Wisconsin, USA
Professor Avner Shaked	University of Bonn, Germany
Professor Ralph Siebert	Wissenschaftszentrum Berlin, Germany
Professor Francesco Squintani	University of Rochester, USA
Professor Konrad Stahl	Faculty, Mannheim University, Germany
Professor Fernando Vega-Redondo	University of Alicante, Spain
Professor Jörgen Weibull	University of Stockholm, Sweden
Professor Menahem Yaari	Hebrew University, Israel
Professor Peyton Young	John Hopkins University, USA

2001-2002

Professor Pierpaolo Battigalli	Milan, Italy
Professor Elchanan Ben-Porath	Hebrew University Jerusalem, Israel
Professor Francis Bloch	Marseille, France
Professor Kalyan Chatterjee	University of Pennsylvania, USA
Professor In-Koo Cho	University of Illinois, USA
Professor Olivier Compte	CERAS, Paris, France
Professor Herve Cres	HEC, Paris, France
Professor Bentley MacLeod	University of Southern California, USA
Professor Massimo Morelli	Ohio State University and Institute for Advanced Studies, USA
Professor Georg Nöldeke	University of Bonn, Germany
Professor Arthur Robson	University of Western Ontario, Canada
Dr. Nicolas Sahuguet	ECARES, Brussels, Belgium
Professor Tim Salmon	Florida State University, USA
Professor Larry Samuelson	University of Wisconsin, USA
Professor Rani Spiegler	Tel Aviv, Israel
Professor Fernando Vega-Redondo	University of Alicante, Spain
Professor Xavier Vives	INSEAD, France
Professor Jörgen Weibull	University of Stockholm, Sweden

4. Post-Graduate Students

C = continuing student

Name	Supervisor	Subject	Date Awarded
V Adamczak	Dunbar	Territorial behaviour in oribi	1999
A. Ahmed	Binmore	Competition in electricity generation	1998
I. Alfon	Ulph	Economics of Regulation	C
K. Araki	Binmore	Evolutionary models of local interaction	C
L. Bellingham	Dunbar	Conflict management in Barbary macaques	2002
G. Bird	Heyes	Observational motor learning	C
M. Boeg	Börgers	Endogenous social interactions	C
F. Campbell	Heyes	Imitative and Nonimitative Social Learning	1999
J. Casperd	Dunbar	Reconciliation in chimpanzees	1998
R. Davies	Harvey	Adaptive decision making and patterns of risk orientation to potential gains and losses in emotionally and behaviourally disturbed adolescents: implications for the reduction of dangerous risky behaviour	1999
P. Dixon	Dunbar	Social cognition and development in baboons	2001
D. Dutton	Dunbar	Personality and socio-cognitive skills in chimpanzees	1999
G. Escherria	Dunbar	Conflict resolution in baboons	C
H. Farrimond	Joffe	Health inequalities in Britain	C
R. Ferreira	Ulph	Product differentiation and innovation	C
C. Foster	Heyes	Sequence learning by observation in rats and humans	1999
L. Hannah-Stewart	Dunbar	Conflict resolution in baboons and chimpanzees	C
M. Gardner	Heyes	The Methodological Adequacy of Directional Control Tests	1997
G. von Graevenitz	Ulph	Competition innovation and cooperation	2002
S. Grainger	Dunbar	Reproductive strategies of young single human mothers	C
B Greiser	Dunbar	Impact of tourism on chimpanzees	1997
D. Hawkins	Dunbar	A test of the baboon time budgets model	1999
A. Hernando	Börgers	Essays on Auction Theory	2000
R. Hill	Dunbar	Behavioural responses to ecological stress in baboons	1999
R. Hoare	Dunbar	Social networks, kinship and childhood morbidity	C
C.-T. Huang	Heyes	Imitation, Emulation and Intention	2001
C. Hunter	Dunbar	Foraging decisions of gelada baboons	2001
A. Ianni	Börgers	Interaction patterns, learning processes, and equilibria in population games	1996
T. Jonnstone	Shanks	Structural versus processing accounts of	1999

		implicit learning	
K. Kaskatis	Dunbar	Evolution and adaptive significance of music	C
D. Lan	Dunbar	Behavioural ecology of gibbons	2000
U. Landwehr	Ulph	Industrial Mobility and Public Policy	1996
C. Lane	Ottaviani	Optimal delegation and monopoly regulation	C
A. Lilico	Jehiel/Börgers	Bounded rationality	C
K. Lloyd	Dunbar	Mating strategies of male feral goats	C
A. Morales	Börgers	Reinforcement learning in decisions and games	1999
N. Mulcahy	Dunbar	Social cognition in great apes	C
M. Nelson	Dunbar	Evolution of grandmaternal strategies	C
D. Nettle	Dunbar	Evolution and diversity of languages	1996
S. O'Connell	Dunbar	Theory of mind in chimpanzees	1995
L. Painter	Dunbar	Behavioural ecology of peccaries	1999
R. Pastor-Nieto	Dunbar	Social behaviour of captive spider monkeys	1997
R. Patino	Dunbar	Adaptive significance of celibacy	C
P. Plancke	Dunbar	Social organisation of tamarin and squirrel monkey groups	2001
G. Ponti	Binmore/ Seymour	Evolutionary dynamics and social evolution	1996
P. Postl	Börgers	Mechanism design for information acquisition	C
D. Prangle	Seymour	Network exchange theory	C
T. Rakow	Harvey	Medical decision making	2000
E. Ray	Heyes	Social and associative learning	1997
P. Rey	Börgers	Psychology, economics and incentives	C
C. Richards	Heyes	Social transmission of stereotypic behaviour	C
R. Salmons	Swierzbinski	Economic instruments for preserving environmental quality	C
M. Schlumberger	Ottaviani	Early mover advantage	C
N. Sevdalis	Harvey	Affective influences on individual decision making	C
S. Shultz	Dunbar	Foraging decisions in an African raptor	C
J. Shi	Dunbar	Foraging decisions of feral goats	2002
S. Singh	Harvey	Motor skill	C
D. Stewart	Harvey	Importance of business environment to forecast accuracy	2000
M. Strate	Dunbar	Vocalisations of gelada baboons	2001
R. Swarbrick	Dunbar	Theory of mind in normal and paranoid humans	2000
A. Voohoeven	Binmore	The concept of equal opportunity and its place in distributive justice	C
N. Vulkan	Binmore/Börgers	Information acquisition and entry in oligopolistic markets	1996
R. Wallace	Dunbar	Behavioural ecology of spider monkeys	1999
L. Wilkinson	Shanks	Implicit sequence learning	C
D. Williamson	Ulph		1997
R. Yap	Swierzbinski	Political and economic factors influencing deforestation	2002
O. Yaari	Binmore	Auctioning gilts	C

5. Membership of Committees Outside the University

M. Agastya

Co-organizer of the ESRC Research seminars in Game Theory (1997-2000).

K. Binmore

Editor of the MIT Press series on Economic Learning and Social Evolution (since 1995).

Associate Editor, *Economics and Philosophy* (1995-1997).

Associate Editor, *International Journal of Game Theory* (1994-1996).

Associate Editor, *Games and Economic Behavior* (1990-1996).

Member of the Council of the Royal Economic Society (1997-2002).

Member of the Council of the European Economic Association (1998-2003).

Member of the Community Health Council for England and Wales' commission for reform of the National Health Service (2000).

Visiting Fellow, Institute for Advanced Studies, Princeton (2001).

Visiting Professor, Department of Economics, University of Bristol (since 2001).

T. Börgers

Member of the Editorial Board, *Review of Economic Studies*, (1995–2001).

Associate Editor, *Ricerche Economiche* (1996-2001).

Member of the Editorial Board, *Mathematical Social Sciences* (since 1998).

Member of the Programme Committee, European Meeting of the Econometric Society (1996, 1997, 1998, 2001, 2002).

Member of the Programme Committee, Annual Meeting of the European Economic Association (2001).

Co-organizer of the ESRC Research seminars in Game Theory (1997-2000).

R. Dunbar

Series Editor, Evolutionary Psychology Series, Oxford University Press.

Associate Editor, *Journal of Human Evolution* (1993-1997).

Member of the Editorial Board, *Behavioural Processes* (since 1984).

Member of the Editorial Board, *Primates* (since 1990)

Member of the Editorial Board, *Human Nature* (since 1998).

Member of the Editorial Board, *Journal of Ethology* (since 1999).

Member of the Editorial Board, *Proceedings of the Royal Society, London (Biology Series)* (since 2001).

Member of the Editorial Board, *Evolutionary Psychology* (since 2001).

Member of the Home Office Animal Procedures Committee (since 1997).

Member of the Scientific Advisory Committee, Fondation J-M. Delwart (Belgian Academy of the Sciences) (since 2000).

Member of the Isle of Rum Ecological Management Committee, Scottish Natural Heritage (since 2000).

Chairman of the Management Committee of the AHRB Research Centre for Evolutionary Analysis of Culture (since 2001).

Special Adviser to the Anthropology Panel in the Research Assessment Exercise (2001).

Member of the Council of the Royal Anthropological Institute (since 2001).

Nigel Harvey

President of the European Association for Decision Making (since 2001).

Member of the Executive, European Association for Decision Making (1999-2000).

Member of the Editorial Board, *Journal of Consumer Psychology* (since 1996).

Member of the Editorial Board, *Journal of Behavioral Decision Making* (since 1993).

Associate Editor, *Thinking and Reasoning* (since 1994).

C. Heyes

Associate Editor, *Biology and Philosophy*, (since 2001).

Consulting Editor, *Animal Behaviour*, (1994-1997).

Associate Editor, *Quarterly Journal of Experimental Psychology: B*. (1988-1997).

Committee Member, Experimental Psychology Society (1994-1998).

Council Member, Primate Society of Great Britain (1998-2001).

Member of the BBSRC audit team, Roslin Institute, Edinburgh (1997).

Representative of the Experimental Psychology Society to the Institute of Biology (1999-2001).

Member of the Steering Committee of the International Conference on 'Perspectives on Imitation; From Cognitive Neuroscience to Social Science', Royaumont, France (2001).

P. Jehiel

Associate Editor of the *Journal of Economics* (since 1996).

Associate Editor of the *Annales d'Economie et de Statistique* (since 1997).

Member of the Editorial Board of the *Review of Economic Studies* (since 1998).

Associate Editor of the *European Economic Review* (since 1999).

Chairman of the Programme Committee, Annual Congress of the European Economic Association (1997).

H. Joffe

Member of the Scientific Committee, 6th International Social Representations Conference (since 2001).

C. Leaver

Associate Member, Centre for Market and Public Organisation, University of Bristol (since 1998).

M. Ottaviani

Member of the Editorial Board, *Review of Economic Studies* (since 2000).

Member of the Advisory Panel, *Economic Policy* (since 2002).

Member of the Program Committee, European Meeting of the Econometric Society (2001).

H. Plotkin

Member of the Editorial Board of *Biology and Philosophy*.

Member of the Editorial Board of *Evolution and Cognition*.

Member of the Editorial Board of *Evolutionary Psychology*.

Member of the Editorial Board of *Intelligent Systems*.

R. Seymour

Member of the steering committee of the Centre for Mathematics and Physics in the Life Sciences and Experimental Biology.

D. Shanks

Consulting Editor, *Memory and Cognition* (since 2001).

Consulting Editor, *Journal of Experimental Psychology* (1994-2001).

Associate Editor, *Quarterly Journal of Experimental Psychology* (1993-1996).

D. Ulph

Member of the “High Level Economic Advisory Group” of the Institute for Prospective Technological Studies.

R. Vaughan

Member of the Broadband Fixed Wireless Access Steering Group of the Radiocommunications Agency (since 2001).

Annex F: Centre Staff CV's

In this Annex we provide short CVs of selected members of ELSE's academic staff. We begin with the current members of the ELSE executive.

Tilman Börgers

Roles in ELSE: Since 2002: Director; 2001–2002: Acting Director; 1998-2001: Deputy Scientific Director; Since 1995: Research Fellow.

Education: Diplom-Volkswirt (Köln, 1983); PhD in Economics (LSE, 1987); Habilitation (Basel, 1993).

Employment: Since 1996: Professor of Economics, UCL; 1993-1996: Reader in Economics, UCL; 1991-1993: Lecturer in Economics, UCL; 1987-1991: Assistent, Universität Basel.

Research Interests: Decision Theory, Game Theory, Microeconomics, Industrial Organisation, Voting.

Selected Publications: 1) Strange Bids: Bidding Behaviour in the United Kingdom's Third Generation Spectrum Auction, mimeo., ELSE, 2001.
2) Learning Through Reinforcement and Replicator Dynamics, *Journal of Economic Theory*, 77 (1997), 1-14 (with Rajiv Sarin).
3) Weak Dominance and Approximate Common Knowledge, *Journal of Economic Theory*, 64 (1994), 265-276.
4) Pure Strategy Dominance, *Econometrica*, 61 (1993), 423-430.
5) Iterated Elimination of Dominated Strategies in a Bertrand-Edgeworth Model, *Review of Economic Studies*, 59 (1992), 163-176.

Professional Duties: *Review of Economic Studies* (1992 – 1994: Assistant Editor, 1994 – 1995: Managing Editor, 1995 – 2001: Member of the Editorial Board); *Ricerche Economiche* (1996 - 2001: Associate Editor); *Mathematical Social Sciences* (since 1998: Member of the Editorial Board).

David Shanks

Roles in ELSE: Since 2002: Scientific Deputy Director; 2001-2002: Scientific Director; 1995-2001: Director of ELSE's Experimental Laboratories; Since 1995: Research Fellow.

Education: B.A. in Natural Sciences (Cambridge, 1982), PhD in Experimental Psychology (Cambridge 1985).

Employment: Since 1999: Professor of Experimental Psychology, UCL; 1996-1999: Reader in Psychology, UCL; 1993-1996: Lecturer in Psychology, UCL; 1985-1990 and 1992: Research Scientist, MRC Applied Psychology Unit, Cambridge; 1991: Research Fellow, Department of Cognitive Science, University of California, San Diego.

Research Interests: Learning, Choices under risk, Bounded Rationality, Causal Learning.

Selected Publications: 1) Take the Best or Look at the Rest? Factors Affecting One-Reason Decision Making, *Journal of Experimental Psychology: Learning, Memory, and Cognition*, forthcoming (with B. Newell).

2) A Re-examination of Probability Matching and Rational Choice, *Journal of Behavioral Decision Making*, 15 (2002), 233-250 (with R. J. Tunney and J. D. McCarthy).

3) Is Causal Induction Based on Causal Power? Critique of Cheng (1997), *Psychological Review*, 107 (2000), 195-212 (with K. Lober).

4) *The Psychology of Associative Learning*, Cambridge: Cambridge University Press, 1995.

5) Characteristics of Dissociable Human Learning Systems, *Behavioral and Brain Sciences*, 17 (1994), 367-447 (with M. F. St. John).

Professional Duties: Since 2001: Consulting Editor, *Memory and Cognition*; 1994-2001: Consulting Editor, *Journal of Experimental Psychology*; 1993-1996: Associate Editor, *Quarterly Journal of Experimental Psychology*.

Richard Vaughan

Roles in ELSE: Since 2002: Administrative Deputy Director of ELSE; 2001-2002: Acting Executive Director of ELSE; 1995-1999: Deputy Executive Director of ELSE; Since 1995: Research Fellow.

Education: MSc in Economics (LSE, 1969), PhD in Economics (Cambridge, 1975).

Employment: Since 1979: Lecturer/Senior Lecturer in Economics, UCL; 1976-1979: Lecturer in Economics, University College Dublin; 1975-1979: Researcher, Economic and Social Research Institute, Dublin.

Research Interests: Evolutionary Game Theory, Industrial Organisation, Income Distribution.

Selected Publications: 1) Evolutive Equilibrium Selection I and II, mimeo., UCL, 1995 and 2002.

2) Musical Chairs: Modelling Noisy Evolution, *Games and Economic Behavior*, 11 (1995), 1-35 (with K. Binmore and L. Samuelson).

3) Welfare Approaches to the Measurement of Poverty, *The Economic Journal*, 97 (1987), 160-170.

4) *The Irish Capital Stock*, ESRI Monograph, Dublin, 1981.

5) Class Behaviour and the Distribution of Wealth, *Review of Economic Studies*, 46 (1979), 447-465.

Professional Duties: Past editor of *The Economic and Social Review*.

Cecilia Heyes

Roles in ELSE: Since 2001: Director of the ELSE experimental laboratories; Since 1995: Research Fellow of ELSE.

Education: BSc in Psychology (UCL, 1981), PhD in Psychology (UCL, 1984).

Employment: Since 2000: Professor of Psychology, UCL; 1996-2000: Reader in Psychology, UCL; 1993-1996: Senior Lecturer in Psychology, UCL; 1988-1993: Lecturer in Psychology, UCL; 1986-1989: Research Fellow, Trinity Hall, Cambridge; 1984-1986: Harkness Fellow of the Commonwealth Fund of New York (University of Chicago, Lehigh University, and Tufts University).

Research Interests: Social Learning, Evolution, Imitation.

Selected Publications: 1) Motor Learning by Observation: Evidence From a Serial Reaction Time Task, *Quarterly Journal of Experimental Psychology*, 55A (2002), 593-607 (with C. Foster).

2) *Evolution of Cognition*, Cambridge: MIT Press, 2001 (with L. Huber, editors).

3) Causes and Consequences of Imitation, *Trends in Cognitive Sciences*, 5 (2001), 253-261.

4) Theory of Mind in Nonhuman Primates, *Behavioral and Brain Sciences*, 21 (1998), 101-114.

5) Reflections on Self-Recognition in Primates, *Animal Behaviour*, 47 (1994), 909-919.

Professional Duties: Since 2001: Associate Editor, *Biology and Philosophy*, 1994-1997: Consulting Editor, *Animal Behaviour*, 1988-1997: Associate Editor, *Quarterly Journal of Experimental Psychology: B*.

Honors: UCL Faculty of Life Sciences Teaching Award (2002).

Steffen Huck

Roles in ELSE: Since 2001: Member of the ELSE executive and Research Fellow of ELSE.

Education: Diplom-Volkswirt (Frankfurt, 1992); Dr. rer. pol. (Humboldt, 1996); Habilitation (Humboldt, 2000).

Employment: Since 2002: Reader in Economics, UCL; 2000-2001: Senior Lecturer in Economics, Royal Holloway College, London; 1998-1999: Research Scholar of the German Science Foundation; 1995-1997: Wissenschaftlicher Mitarbeiter, Humboldt University, Berlin; 1993-1994: Wissenschaftlicher Mitarbeiter, Goethe University, Frankfurt.

Research Interests: Experimental Economics, (Evolutionary) Game Theory, Learning and Bounded Rationality, Industrial Economics, Law and Economics, Microeconomics.

Selected Publications: 1) Stability of the Cournot Process: Experimental Evidence, *International Journal of Game Theory*, forthcoming (with H.-T. Normann and J. Oechssler).

2) The Relevance of Equal Splits in Ultimatum Games, *Games and Economic Behavior*, 37 (2001), 161-169 (with W. Güth and W. Müller).

3) More Order With Less Law: On Contract Enforcement, Trust, and Crowding, *American Political Science Review* 95 (2001), 131-144 (with I. Bohnet and B. S. Frey).

4) Perfect vs. Imperfect Observability: An Experimental Test of Bagwell's Result, *Games and Economic Behavior* 31 (2000), 174-190 (with W. Müller).

5) Learning in Cournot Oligopoly: An Experiment, *The Economic Journal* 109 (1999), C80-C95 (with H.-T. Normann and J. Oechssler).

Robert Seymour

Roles in ELSE: Since 2001: Member of the Executive; 1999-2001: Deputy Executive Director; Since 1995: Research Fellow.

Education: BA in Mathematics (Cambridge, 1966); MSc in Mathematics (Warwick, 1967); PhD in Mathematics (Warwick, 1970).

Employment: Since 2002: Professor of Mathematics, UCL; 1994-2002: Reader in Mathematics, UCL; 1971-1994: Lecturer in Mathematics, UCL.

Research Interests: Mathematical Biology, Evolutionary Game Theory.

Selected Publications: 1) The Stability of Price Dispersion Under Seller and Consumer Learning, *International Economic Review*, in press (with E. Hopkins).

2) Optimal Resource Consumption, Discrete Dynamics and Intraspecific Competition, *Theoretical Population Biology*, 45 (1994), 132-166.

3) Is the Crown-of-Thorns Starfish Degrading the Great Barrier Reef?, *Journal of Theoretical Biology*, 159 (1992), 111-133 (with R. H. Bradbury).

4) A Study of the Interaction of Virulence, Resistance and Resource Limitation in a Model of Myxomatosis Mediated by the European Rabbit Flea *Spilopsyllus Cuniculi* (Dale), *Ecological Modelling*, 60 (1992), 281-308.

5) Some Functorial Constructions on G-Spaces, *Bulletin of the London Mathematical Society*, 15 (1983), 353-359.

Gian-Luigi Albano

Roles in ELSE: Since 2001: Research Fellow.

Education: PhD in Economics (Louvain, 1998), MA in Economics (Louvain, 1995), Undergraduate Degree in Economics (Bocconi, 1992).

Employment: Since 1999: Lecturer in Economics, UCL.

Research Interests: Theory of Organisations, Contract Theory, Economics of Information, Auction Theory, Econometrics of Auctions.

Selected Publications: 1) Strategic Certification and Provision of Quality, *International Economic Review*, 42 (2001), 267-283 (with A. Lizzeri).
2) A Class of All-Pay Auctions with Affiliated Information, *Louvain Economic Research*, 67 (2001), 31-37.
3) A Comparison of Standard Multi-Unit Auctions with Synergies, *Economics Letters*, 71 (2001), 55-60.

Ken Binmore

Roles in ELSE: 1995-2001: Director; Since 1995: Research Fellow.

Education: BSc in Mathematics (London, 1962), PhD in Mathematics (Imperial College London, 1965).

Employment: Since 1991: Professor of Economics, UCL; Since 2001: Visiting Professor of Economics, Bristol; 1988-1993: Professor of Economics, Michigan; 1988-1990: Professor of Economics, LSE; 1969-1988: Lecturer, Reader and Professor of Mathematics, LSE; 1965-1969: Lecturer in Mathematics, Royal Holloway College.

Research Interests: Mathematical Economics, Game Theory, Bargaining, Experimental Economics, Evolutionary Psychology, Political Philosophy, Mathematical Analysis..

Selected Publications: 1) Equilibrium Selection and Evolutionary Drift, *Review of Economic Studies*, 66 (1999), 363-394 (with L. Samuelson).
2) *Game Theory and The Social Contract: I and II*, Cambridge: MIT Press, 1994 and 1998.
3) Modeling Rational Players I and II, *Economics and Philosophy*, 3 (1987) and 4 (1988), 179-214 and 9-55.
4) Nash Bargaining Theory I, II and III, in: K. Binmore and P. Dasgupta (editors), *Economics of Bargaining*, Oxford: Basil Blackwell, 1986.
5) Analytic Functions with Hadamard Gaps, *Bulletin of the London Mathematical Society* 1 (1969), 211-217.

Professional Duties: Since 1995: Editor of the MIT Press series on Economic Learning and Social Evolution; 1995-1997: Associate Editor, *Economics and Philosophy*, 1994-1996: Associate Editor, *International Journal of Game Theory*, 1990-1996: Associate Editor, *Games and Economic Behavior*; 1980-1988: Editorial Board of *Economica*. 1997-2002: Member of the Council of the Royal Economic Society; 1998-2003: Member of the Council of the European Economic Association.

Honours: 2002: Foreign Honorary Member of the American Academy of Arts and Sciences; 2001: Commander of the British Empire; 1995: Fellow of the British Academy; 1988: Fellow of the Econometric Society.

Robin Dunbar

Roles in ELSE: 1995-2001: Dissemination Director; Since 1995: Research Fellow.

Education: BA in Psychology and Philosophy (Oxford, 1969), PhD in Psychology (Bristol, 1973).

Employment: Since 1997: Professor of Evolutionary Psychology, Liverpool; 1994-1997: Professor of Psychology, Liverpool; 1992-1994: Professor of Biological Anthropology, UCL; 1990-1992: Reader in Anthropology, UCL; 1987-1990: Lecturer in Anthropology, UCL; 1985-1987: University Research Fellow, Liverpool; 1984-1985: Research Associate, Cambridge; 1983: Assistant Professor, Stockholm; 1977-1982: SERC Advanced Research Fellow, Cambridge; 1974-1977: Post-doctoral Research Associate, Bristol.

Research Interests: Human Behavioural Ecology, Cognitive Bases of Social Behaviour.

Selected Publications: 1) Barrett, L., R. I. M. Dunbar and J. Lycett, *Human Evolutionary Psychology*, (with L. Barrett and J. Lycett), Basingstoke: Palgrave/Macmillan, and Princeton: Princeton University Press, 2002.
2) The Economics of Male Mating Strategies Among Primates, in: J. van Hooff, R. Noë and P. Hammerstein (editors), *Economic Models of Animal and Human Behaviour*, Cambridge: Cambridge University Press, 245-269.
3) Neocortex Size and Social Network Size in Primates, *Animal Behavior*, 62 (2001), 711-722 (with H. Kudo).
4) Tall Men Have More Reproductive Success, *Nature*, 403 (2000), 156 (with B. Pawlowski and A. Lipowicz).
5) Impact of Market Value on Human Mate Choice Decision, *Proceedings of the Royal Society of London, B*, 266 (1999), 281-285 (with B. Pawlowski).

Professional Duties: Series Editor, Evolutionary Psychology Series, Oxford University Press. Associate Editor, *Journal of Human Evolution*, 1989-1991 and 1993-1997; European Co-editor, *Animal Behaviour*, 1994-1995. Member of the following editorial boards: *Behavioural Processes* (1979-1982 and since 1984), *Animal Behaviour* (1983 and 1991-1993), *Primates* (since 1990), *Behaviour* (1992-1993), *Human Nature* (since 1998), *Journal of Ethology* (since 1999), *Proceedings of*

the Royal Society, London (Biology Series) (since 2001), *Evolutionary Psychology* (since 2001).

Honors: Fellow of the British Academy (1998).

Nigel Harvey

Roles in ELSE: Since 1998: Research Fellow.

Education: DPhil in Psychology (Oxford, 1974), BSc in Psychology (Hull, 1969).

Employment: Since 2001: Professor of Judgement and Decision Research, UCL; 1992-2001: Reader in Experimental Psychology, UCL; 1976-1992: Lecturer in Psychology, UCL; 1974-1976: Lecturer in Psychology, St Andrews; 1973-1974: College Lecturer, St Edmund Hall, Oxford.

Research Interests: Forecast and Control of Time Series; Risk assessments.

Selected Publications: 1) Using Advice and Assessing Its Quality, *Organizational Behavior and Human Decision Processes*, 81 (2000), 252-273 (with C. Harries and I. Fischer).

2) Why are Judgements Less Consistent in Less Predictable Task Situations?

Organizational Behavior and Human Decision Processes 63 (1995), 247-263.

3) Judgmental Forecasting of Univariate Time Series, *Journal of Behavioral Decision Making* 1 (1988), 95-110.

4) Non-Informative Effects of Stimuli Functioning as Cues, *Quarterly Journal of Experimental Psychology* 32 (1980), 413-435.

5) Switching Attention Between Ears to Monitor Tones, *Perception and Psychophysics* 14 (1973), 51-59 (with A. M. Treisman).

Professional Duties: Since 2001: President of the European Association for Decision Making; Since 1996: Editorial Board Member, *Journal of Consumer Psychology*; Since 1993: Editorial Board Member, *Journal of Behavioral Decision Making*; Since 1994: Associate Editor, *Thinking and Reasoning*; 1988-1996: Associate Editor, *Human Movement Science*; 1981-1989: Associate Editor, *Quarterly Journal of Experimental Psychology*.

Philippe Jehiel

Roles in ELSE: Since 1997: Research Fellow of ELSE.

Education: PhD in Economics (EHESS, Paris, 1992).

Employment: Since 1997: Professor of Economics, UCL; Since 1990: Research Fellow of CERAS.

Research Interests: Auction Theory, Mechanism Design, Bargaining Theory, Game Theory, Bounded Rationality, Organization Theory, Decentralization, Institutional Economics.

Selected Publications: 1) Efficient Design With Interdependent Valuations, *Econometrica*, 69 (2001), 1237-1259 (with Benny Moldovanu).
2) Limited Foresight May Force Cooperation, *Review of Economic Studies* 68 (2001), 369-391.
3) Multidimensional Mechanism Design for Auctions with Externalities, *Journal of Economic Theory* 85 (1999), 258-293 (with Benny Moldovanu and Ennio Stacchetti).
4) How (Not) To Sell Nuclear Weapons, *American Economic Review*, 86 (1996), 814-829 (with Benny Moldovanu and Ennio Stacchetti).
5) Negative Externalities May Cause Delay In Negotiation, *Econometrica* 63 (1995), 1321-1335.

Professional Duties: Since 1996: Associate editor of *Journal of Economics*; since 1997: associate editor of *Annales d'Economie et de Statistique*; since 1998: member of the editorial board of *Review of Economic Studies*; since 1999: associate editor of *European Economic Review*.

Henry Plotkin

Roles in ELSE: Deputy Scientific Director, 1995-1997; Scientific Director, 1997-2001; Since 1995: Research Fellow.

Education: Education: B.Sc. Hons in Zoology and Psychology (University of the Witwatersrand); PhD (University of London); Postdoctoral Fellow (Stanford).

Employment: Professor of Psychobiology, UCL; Since 1972: Member of the Academic Staff, Department of Psychology, UCL; 1965-1972: Scientist, Medical Research Council of the UK; before: Research Assistant at the University of the Witwatersrand.

Research Interests: Evolutionary Psychology.

Selected Publications: 1) *The Imagined World Made Real: Towards a Natural Science of Culture*, London: The Penguin Press, 2002.
2) Intelligence, the Evolution of, in: W. Durham and M. W. Feldman (section editors), *Evolutionary Sciences*, in: N. J. Smelser and P. B. Bales (editors in chief): *International Encyclopedia of the Social and Behavioural Sciences*, Oxford: Pergamon-Elsevier, Vol. 11, 7641-7645, 2001.
3) *The Nature of Knowledge*, London: The Penguin Press, 1994. (Published in North America as: *Darwin Among the Machines and the Nature of Knowledge*, Harvard: Harvard University Press.)
4) Evolutionary Epistemology as Science, *Biology and Philosophy*, 2 (1987), 292-131.
5) Learning, Change and Evolution, *Advances in the Study of Behaviour*, 10 (1979), 1-41.

Professional Duties: Member of the Editorial boards of: *Biology and Philosophy*; *Evolution and Cognition*; *Evolutionary Psychology*; *Intelligent Systems*.

Joseph Swierzbinski

Roles in ELSE: Since 1995: Research Fellow of ELSE.

Education: A.B. in Physics (Princeton, 1975), Diploma in Mathematical Statistics (Cambridge, 1976), PhD in Applied Mathematics (Harvard, 1981).

Employment: Since 1994: Senior Lecturer in Economics, UCL; 1988-1994: Assistant Professor of Economics and Natural Resources, Michigan; 1986-1988: Visiting Assistant Professor of Economics, Michigan; 1981-1988: Assistant Professor of Economics, University of Washington.

Research Interests: Natural Resource and Environment Economics; Experimental Economics; Industrial Economics; Auctions.

Selected Publications: 1) Does Minimax Work? An Experimental Study, *Economic Journal*, 111 (2001), 445-464 (with K. Binmore and C. Proulx).
2) Hard Bargains and Lost Opportunities, *Economic Journal*, 108 (1998), 1279-1298 (with K. Binmore, C. Proulx, and L. Samuelson).
3) Focal Points and Bargaining, *International Journal of Game Theory*, 22 (1993), 381-409 (with K. Binmore, S. Hsu and C. Proulx).
4) Durable-Goods Monopoly with Discrete Demand, *Journal of Political Economy*, 97 (1989), 1459-1478 (with M. Bagnoli and S. Salant).
5) Exploration and Exhaustible Resources: The Microfoundations of Aggregate Models, *International Economic Review*, 30 (1989), 175-186 (with R. Mendelsohn).

Professional Duties: Former member of the Editorial Council of the *Journal of Environmental Economics and Management*.