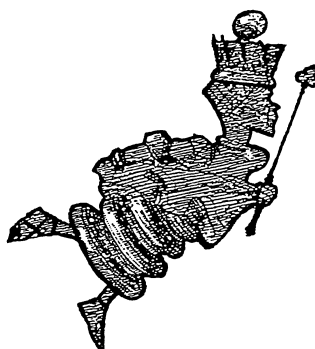




**Centre for Economic Learning
and Social Evolution
(ELSE)**



**Activities 1995 – 2002
A Report for the ESRC**



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

Executive Committee

Director: Tilman Börgers (Professor of Economics)

Scientific deputy director: David Shanks (Professor of Psychology)

Administrative deputy director: Richard Vaughan (Senior Lecturer in Economics)

Director of the experimental laboratories: Cecilia Heyes (Professor of Psychology)

Member of the executive: Steffen Huck (Reader in Economics)

Member of the executive: Rob Seymour (Professor of Mathematics)

Administrator: Rosie Mortimer

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

Heads of Research Divisions

Evolutionary Approaches: Ken Binmore (Professor of Economics)

Learning Approaches: David Shanks (Professor of Psychology)

Behavioral Economics: Tilman Börgers (Professor of Economics)

Mechanism Design: Philippe Jehiel (Professor of Economics)

Automated Trading and Negotiation: Richard Vaughan (Senior Lecturer in Economics)

Industrial Organisation: Steffen Huck (Reader in Economics)

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

Research Fellows

Dr Gian Luigi Albano	Economics, UCL
Professor Ken Binmore	Economics, UCL
Professor Tilman Börgers	Economics, UCL
Professor Robin Dunbar	Anthropology, Liverpool
Dr Georg von Graevenitz	Economics, UCL
Dr Antonio Guarino	Economics, UCL
Professor Nigel Harvey	Psychology, UCL
Professor Celia Heyes	Psychology, UCL
Dr Steffen Huck	Economics, UCL
Professor Philippe Jehiel	Economics, UCL
Dr Helene Joffe	Psychology, UCL
Dr Nathan Larson	Economics, UCL
Dr Clare Leaver	Economics, UCL
Dr Alexander Matros	Economics, UCL
Dr Ben Newell	Psychology, UCL
Dr Magda Osman	Psychology, UCL
Dr Marco Ottaviani	Economics, London Business School
Professor Henry Plotkin	Psychology, UCL
Dr Roger Salmons	Economics, UCL
Professor Rob Seymour	Mathematics, UCL
Professor David Shanks	Psychology, UCL
Dr Joe Swierzbinski	Economics, UCL
Dr Richard Vaughan	Economics, UCL
Dr Nir Vulkan	Economics, Saïd Business School

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

Director's Foreword

The "Centre for Economic Learning and Social Evolution" at University College London was established in 1995. The centre is funded jointly by the Economic and Social Research Council (ESRC) and by University College London. The centre's mission, as agreed between the ESRC and University College London, is to "to provide a new foundational basis for modelling in economics and related social sciences."

The current ESRC funding for the centre lasts until 2005. In the academic year 2002/2003 the centre will be reviewed by an Evaluation Panel appointed by the ESRC. The purpose of the review will be to establish whether the centre should be given permission to apply for ESRC funding beyond the year 2005. This report was prepared by the centre for the Evaluation Panel. The report follows a format specified by the ESRC.

The report documents considerable achievements in the areas of fundamental research and interaction with non-academic users of our research. The report demonstrates a strong case for continued ESRC funding of the centre.

September 2002

Tilman Börgers
Director of ELSE

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

Table of Contents

1. Centre's History and Objectives	pp. 7-12
2. Research Objectives	pp. 13-30
3. Other Objectives	pp. 31-37
4. Management	pp. 38-45
5. ESRC and Non-ESRC Funding	pp. 46-49
6. The Wider Picture	pp. 50-54
7. Future Plans	pp. 55-59

1. Centre's History and Objectives

1.1 Introduction and Background

The *Centre for Economic Learning and Social Evolution* (ELSE) was created in the autumn of 1995. It is an interdisciplinary research centre based at *University College London* (UCL). It involves economists, psychologists, anthropologists, and mathematicians. Its core funding comes from the *Economic and Social Research Council* (ESRC) and from *University College London*. The centre is an ESRC Research Centre.

ELSE's mission, as described in the ESRC's award letter, is to "provide a new foundational basis for modelling in economics and related social sciences." Among the 23 research centres that the ESRC currently funds, ELSE is the only one that is primarily engaged in fundamental research about methodological issues.

ELSE is mostly concerned with human decision making in the economic domain. But it also studies human behaviour in other areas of interest to the social sciences. To achieve a new foundational basis for modelling in these areas, ELSE pursues research about the evolutionary background to human behaviour, and about the importance of learning for human decision making.

Most interactions in the economic domain of human life, but also in other areas, can best be described as "games". Here, we use the expression "games" in the technical sense introduced by "game theory", that is, we mean by it the strategic interaction of individuals, each pursuing its own objective. ELSE is interested in the mod-

elling of human behaviour in "games", and therefore pursues evolutionary and learning approaches to games.

ELSE was given the research task specified in the ESRC award letter because it was the ESRC's opinion, and also the opinion of the researchers involved in ELSE, that there was a need to consider the foundations of modelling human behaviour in economics and other social sciences. The view that evolutionary forces and learning shaped much of human behaviour was gaining ground among economists and social scientists. This theme, however, had not been explored much, and needed deeper investigation. Game theorists also hoped to gain insights into important and difficult technical problems of their discipline, such as the equilibrium selection problem.

Before ELSE began, the ESRC had commissioned a research programme entitled "Economic Beliefs and Behaviour". ELSE picked up the theme of that research programme, and developed it further.

ELSE was based at University College London because that university combined particular expertise in several relevant areas. With the arrival of Ken Binmore in the early 1990s, the economics department of UCL had acquired one of the most eminent game theorists. Henry Plotkin in the psychology department and Robin Dunbar in the anthropology department were outstanding researchers with expertise in the evolutionary foundations of human behaviour. David Shanks in psychology and Tilman Börgers in economics were both strongly interested in developing research on learning theory. Binmore and Shanks both had much experience in experimental research.

Since its creation in 1995 ELSE has pursued its foundational research programme with great vigour. Researchers at ELSE have made outstanding contributions to evolutionary psychology, evolutionary game theory, to the theoretical and experimental study of learning, and to various areas of applied economics. In particular, Dunbar and Plotkin did leading work in evolutionary psychology. Dunbar's and Plotkin's research, as well as that of Miller, a post-doctoral research fellow at ELSE, gained a lot of attention in the media. The ELSE seminar series was a forum for researchers from throughout the UK who were interested in evolutionary psychology.

Binmore and his co-authors advanced significantly the theory of stochastic evolution in games. Binmore also brought evolutionary thinking into political philosophy. Börgers and his co-authors explored learning models and their relation to evolutionary models. Shanks initiated a re-consideration of experimental research on learning among psychologists.

Jehiel's work with Moldovanu on auctions has helped to reshape the research agenda in this area. Ulph has made leading contribution to the theory of Research Joint Ventures.

When ELSE was created, the ESRC urged UCL, and the researchers involved, that ELSE, like all ESRC research centres, should produce research that was of practical use, and that it should interact closely with non-academic users of its research. ELSE has taken its commitment to such interaction very seriously, and has advised many government institutions as well as private businesses.

In retrospect, the documents in which the ESRC's concerns relating to user

engagement were expressed, and the researchers' efforts to address these concerns, make amusing reading. Neither the ESRC nor the researchers involved foresaw at the time, that is in 1994, the nature and the extent of the policy impact ELSE was ultimately going to have.

ELSE's most prominent engagement with non-academic users was the advice which it offered in collaboration with Professors Klemperer (Oxford) and Bulow (Stanford) to the Radio-communications Agency of the UK government regarding the auction of spectrum licenses for third generation mobile telephony. This auction took place in the year 2000. It raised about £22.5 billion. The large success of this auction in terms of revenue raised has been widely attributed to the careful academic advice that the government received.

It is worthwhile to ponder the dimension of the revenue from the spectrum auction. The amount raised in the auction is about 288 times the total income of the ESRC in the year 1999/2000.

The significance of this work in the overall ESRC-portfolio is perhaps best described in the words of the ESRC's Chief Executive, Gordon Marshall:

“These days, Research Councils constantly have to justify the public money that goes into research in terms of its outcomes and impact. I am delighted to say that there have been a number of major successes for ESRC in recent months. The most spectacular example is the work of our Centre for Economic Learning and Social Evolution, led by Ken Binmore, which was behind the mobile phone licence auction that netted the extraordinary sum of over £22 billion for the Treasury.

The research on game theory and mechanism design on which the auction was based is just the kind of 'blue skies' work that some would dismiss as too theoretical and insufficiently connected to the real world. How wrong people can be."

(Source: Chief Executive's Statement, ESRC Annual Report 1999/2000.)

This comment reflects the ESRC's surprise at the public impact of our centre. Our own surprise has been no smaller.

The experience of the past seven years has taught us more about what we can do, and how we can be useful to society at large. We have expanded our range of activities into a variety of other areas. This expansion is reflected by the following paragraph with which the above quote continues:

"This work has already had an enormous positive impact on the public finances but its value is by no means restricted to radio-communications. Economists are now designing markets across a wide range of industries, including electricity, environmental emissions trading, the TV rights for Premiership football and business-to-business internet transactions."

This list reflects the variety of areas into which we have expanded our activities.

ELSE's practical work has absorbed a large proportion of our resources, in particular in terms of work hours. It has diversified ELSE's work more than originally envisaged, and perhaps too much. Although ELSE's fundamental research is connected to auctions, the link is not extremely close, and applied research on auctions ultimately requires a different set of skills and ex-

pertise than fundamental research on evolution and learning. Dealing with this over-diversification is one of the tasks which ELSE's management has to address in the next few years.

Although it absorbed a large proportion of our resources, the revenue from advisory work which we have undertaken has only made up the smaller part of the total co-funding, beyond ESRC core funding, which ELSE has raised. The total amount of co-funding raised so far exceeds the ESRC's contribution.

The most important success in this area has been that we won a bid to the "Joint Infrastructure Fund" which brought in £815,000 to fund a new laboratory for experiments. This bid was co-ordinated by David Ulph, then executive director of ELSE.

David Ulph was also instrumental in raising large amounts of co-funding from the European Community. An example is the funding for a European project on "Growth, Inequality, and Training" which David Ulph co-ordinated, and in which a number of other European universities were involved.

Raising these amounts of co-funding has demanded a very significant time investment, in particular from the executive director of ELSE. Without ESRC core funding it would not have been possible to make this time available.

ELSE's personnel structure has evolved over the years. Robin Dunbar, one of the original applicants, moved shortly after ELSE's creation to the University of Liverpool, and has therefore been less directly involved in ELSE's work than had originally been anticipated. On the other hand, David

Ulph, who was chairman of the economics department at UCL when ELSE was created, played a larger role in ELSE once his chairmanship of the department ended.

The first Director of ELSE was Ken Binmore. He continued in this role until 2001 when he decided to take extended leave from UCL, which is to be followed by his early retirement from his UCL position in 2003 due to ill health. He has been succeeded in 2002 as director of ELSE by Tilman Börgers. Börgers was acting director of ELSE from 2001 until 2002.

During Binmore's directorship of ELSE he was supported by an Executive Director. The first Executive Director of ELSE was Ray Jackson, who held this position until 1997. The second executive director was David Ulph, who took the position up in 1997, and who left ELSE in 2001 to become Director of Research and Analysis at the Inland Revenue.

ELSE now has two deputy directors. The scientific deputy director is David Shanks, while the administrative deputy director is Richard Vaughan. Implementing several management changes has been an important challenge to the ELSE team.

In this report we shall set out how ELSE has worked towards its objectives in the past seven years, and how it will continue its work in the remaining three years of its funding period. We begin with a review of these objectives.

1.2 Objectives

The objectives of ELSE are established in an agreement between the ESRC and University College London. These

objectives include firstly ones which the ESRC sets all of its research centres:

- to demonstrate the benefits of shared knowledge across several related disciplines;
- to demonstrate the benefits of a large research group normally working in a single Research Centre with shared facilities.

This agreement then defines as the overall objective of ELSE to “provide a new foundational basis for modelling in economics and related social sciences”.

The agreement with the ESRC defines in more detail the scientific programme conducted by ELSE: “The Research Centre's scientific work will consist of a programme of empirical, theoretical and applied research”. The scientific work is divided into the work programmes of six research divisions. These research divisions are:

1. Evolutionary Approaches
2. Learning Approaches
3. Behavioural Economics
4. Mechanism Design
5. Automated Trading and Negotiation
6. Industrial Organisation

For each of these research divisions, the agreement between the ESRC and ELSE lays out a more detailed research programme.

The agreement between ELSE and the ESRC in addition specifies a number of further objectives for the centre:

- (a) to publish significant theoretical findings in refereed journals, books, and reports, together with articles for a more general readership;

- (b) to establish ELSE as a focus of collaboration within the scientific community and with potential users of its scientific programme, both nationally and internationally;
- (c) to seek co-sponsorship for work which complements the Centre's research programme;
- (d) to develop links with users through seeking their advice on the research programme, through publications, seminars and conferences, through teaching programmes and other means;
- (e) to develop and implement a dissemination and publicity strategy for the Centre to bring new findings to the attention of both the academic community and of non-academic users, and to contribute to debates on public policy;
- (f) to advance methodology and substantive knowledge in the area of study, by such means as research seminars for the wider academic community and training in research methods;
- (g) to engage actively in the training of postgraduate research students;
- (h) to collaborate with other ESRC Centres and Programmes.
- (i) to develop a strategy for the co-funding of the Centre with a view to sustaining it following the end of the award.

1.3 Changes in Objectives

The basic scientific objective of ELSE has not changed during its lifetime. The structure of ELSE's research divisions has undergone two major changes in ELSE's history. On each of these two occasions, the detailed research programme of these two divisions was also updated to reflect new research developments. There has also

been one change in the further objectives of ELSE.

We begin by describing changes in ELSE's research divisions. When ELSE was founded, the research divisions of ELSE were:

1. Evolutionary Game Theory
2. Rationality and Learning
3. Social Organisation and Social Change
4. Experimental Division
5. Applied Projects
6. Industrial Organisation and Innovation

After the first three years of ELSE's work, it was found that work in the third division could be re-assigned to the first two divisions. Moreover, divisions 4 and 5 seemed to correspond to activities that went across all research divisions. On the other hand, it seemed appropriate to add a division on mechanism design, as ELSE had begun to offer consultancy work in the area of auctions, and a division on automated trading and negotiation as electronic commerce was evidently gaining in importance. Accordingly, from 1998 the five research divisions of ELSE were:

1. Evolutionary Approaches
2. Learning Approaches
3. Mechanism Design
4. Automated Trading and Negotiation
5. Industrial Organisation and Innovation

A division on behavioural economics was added in 2001, the justification being that this field was gaining importance among economists, and that the interdisciplinary work of economists and psychologists, which is characteristic of this field, is a comparative strength of ELSE.

Each change in research divisions went along with an updating of the research programme of the research divisions. This updating reflected research progress, and it also reflected the emergence, through ELSE's engagement with non-academic users, of new issues for research.

The other objectives of ELSE have been subject to only one change. The objectives (h) and (i) listed above were added in 2000, when ELSE's funding was renewed. It should be mentioned, however, that obviously these objectives were also pursued in the first five years of ELSE's operation.

2. Research Objectives

2.1 Progress Towards Research Objectives

The overall research objective of ELSE is to “provide a new foundational basis for modelling in economics and related social sciences”. We have made progress towards this objective by:

- Studying how different evolutionary forces (adaptation, mutation, sexual selection) work;
- Investigating the circumstances in which evolution brings about equilibrium in actions;
- Demonstrating how evolution can select among multiple equilibria;
- Investigating how evolution can shape other determinants of human behaviour, such as preferences, cognition, and ethical attitudes;
- Analysing different forms of learning from one’s own experience, and learning through imitation;
- Analysing when learning processes lead to economic equilibrium.

ELSE has brought a combination of analytical methods and experimental and empirical research to these topics.

ELSE’s involvement with non-academic users in the area of auction advice has stimulated complementary fundamental research in the area of auctions. Although this research does not directly contribute to ELSE’s primary objective, it is by now crucial to ELSE’s mission. We have advanced knowledge in this area by:

- Clarifying the role of externalities in auctions;
- Developing an extensive experimental research programme on auctions.

2.2 Interdisciplinarity and Scale Effects

Two objectives to which all research centres of the ESRC are committed are firstly, to demonstrate the benefits of shared knowledge across several related disciplines, and secondly to demonstrate the benefits of a large research group working in a single centre with shared facilities.

Turning first to interdisciplinarity, we note that interdisciplinarity can take many forms. In our centre it has most of the time taken the form of an exchange of ideas among several disciplines, which thus stimulated and changed each others’ thinking, rather than the form of explicit interdisciplinary work on joint papers.

An example of how interdisciplinary interaction has changed our thinking is the re-direction of Shanks’ research group in psychology, which includes Newell, Tunney, and Lagnado, towards work on decision-making. This was prompted by the perspective on economic rationality that is taken by the economists in ELSE. Another example is the way in which Börgers’ work on learning has been influenced by psychological research in this area. Börgers has brought mathematical models of learning that were first developed by psychologists into the mainstream of game theoretic research. He has then analysed the properties of these learning models from a perspective which was motivated by evolutionary game theory, and which had not occurred to the psychologists who originally developed the models.

We also mention that Binmore’s work on evolution and altruism has been much informed by anthropology. And,

finally, there has been much interaction between the applied mathematician in our group (Seymour) and the evolutionary game theorists.

The interdisciplinarity of ELSE has thus brought major research benefits. However, one might have hoped that ELSE could go one step further, and form a coherent interdisciplinary group working jointly on the same issues. A major impediment towards such a development is that the researchers in our centre are tied into academic departments that attach the highest importance to their ranking in the “Research Assessment Exercise”. The Research Assessment Exercise values publications in highly ranked field journals, and research that is not clearly committed to the methods and standards of a single research area has difficulties to achieve publication in such field journals.

Many researchers in the ELSE group have been young, and have had to maintain a focus on their career prospects, both at UCL and at other universities. These career prospects mainly depend on field specific work rather than interdisciplinary work.

A final point to mention is that many of ELSE’s resources have simply been absorbed by our applied work in the auction area. This work is naturally more field (economics) related. Few resources remained for the development of joint projects across disciplines.

We plan to use the remaining funding period of ELSE to strengthen its interdisciplinary element. As the extent of our applied work will be somewhat reduced, we shall have more resources for interdisciplinary work. More researchers in ELSE have reached a seniority level that allows them to conduct

interdisciplinary research more freely. Finally, we shall hire post-doctoral researchers whose contract will explicitly include the obligation to work with researchers from both disciplines. Obviously, this will be possible only in conjunction with careful career advice for these researchers.

Turning to the second objective that the ESRC sets all of its research centres, we note that ELSE has exploited very significant scale effects:

- Common experimental facilities are employed by researchers from a variety of disciplines;
- An extensive visitors’ programme with visitors who are of interest to researchers in several disciplines has become possible;
- Researchers from several disciplines are supported by the same research support and administrative staff.

2.3 Progress of the Research Divisions

(a) Evolutionary Approaches

Our research division on Evolution has been at the very heart of ELSE from our first year onwards. All eight specific projects in this division that are listed in Annex A were begun in 1995 and most of them are still ongoing in Year 7.

A central endeavour has been to study how biological or cultural evolution might select among multiple equilibria in games. Not so long ago, economists were 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 being more plausible

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 an adaptive stochastic process.

Research by Kandori, Mailath, Rob, and Young popularised in the early 1990s the idea that stochastic mutations could, in the long run, shake evolutionary systems sufficiently to make certain equilibria much more plausible than others. Our research has been aimed at analysing the foundations for this claim, and at extending the applicability of stochastic evolutionary models.

In a joint research effort, Binmore and Vaughan, together with Samuelson (*Games and Economic Behavior*, 1995), have studied what they call the long-run predictions of such 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. Thus, the work of Binmore, Samuelson and Vaughan suggests that the importance of random mutations is less than earlier work had claimed.

Binmore, in joint work with Samuelson (*Journal of Economic Theory*, 1997), has studied equilibrium selection in extensive games where the selection problem is magnified as there are typically an infinite number of equilibria. 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 exploit this phenomenon to study the conditions under which a variety of different types of equilibria may be able to survive.

Another key objective of our research in evolutionary theory was to advance the mathematical modelling of evolutionary dynamics in order to analyse whether evolutionary concepts can help explain when and why the theory of rational behaviour performs well, and when and why it does not. 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.

Seymour and Vaughan have investigated the link between individual dynamics and aggregate population dynamics. They consider a large, heterogeneous population of agents, in which each agent is programmed with a particular type-characterising 'attribute'. In related work, Matros (*Journal of Economic Theory*, 2002) has modelled an evolutionary process with multiple decision rules. For finite n-player games he has proved that the long run predicted outcome is the same minimal curb configurations as obtained for Young's adaptive learning process when the error rate is zero provided that every individual has a set of rules, which contains (i) an imitation rule, (ii) the best reply rule, and (iii) possibly other higher degree best replies.

Binmore and Samuelson (*Games and Economic Behavior*, 2001; *Journal of Theoretical Biology*, 2001) have tackled the evolutionary stability of mixed strategies. They show 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 has developed a general theory of 'Positive Definite-Adaptive' (PDA) evolutionary dynamics for (asymmetric) games with continuous pure strategy sets that are subsets of some Euclidean space. Mixed strategies are then probability measures on the Borel subsets of these pure strategy spaces. Seymour showed that, under mild assumptions on the class of PDA dynamics, asymptotically stable dynamic equilibria are Nash equilibria satisfying certain strictness conditions.

Further projects were concerned with the application of evolutionary theory to economically significant issues. We tackled bargaining problems and several smaller problems where evolutionary methods seemed particularly promising. Binmore, in joint work with Larry Samuelson and John Gale (*Games and Economic Behavior*, 1995), has studied the ultimatum game where experimental evidence shows that subjects fail to play according to the subgame perfect equilibrium. Analysing a slightly perturbed version of the replicator dynamics they find that these do not converge on the subgame perfect outcome, but on a split of the money that resembles experimental

findings. They interpret this result as meaning that it is not necessary to invent exotic behavioural theories to explain the data from the ultimatum game. Whereas Binmore, Samuelson and Gale work with a simplified version of the Ultimatum Game in which only a small number of offers is considered, Seymour (*Journal of Mathematical Sociology*, 2000) has analysed a model for the original, infinite game. This requires the study of the infinite-dimensional replicator dynamics with mutational noise which 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. More complex bargaining protocols have also been studied (Binmore, Piccione and Samuelson, *Journal of Economic Theory*, 1998) and we supplemented our theoretical research by conducting experiments on bargaining problems.

Binmore has been engaged in a wide-ranging project whose aim 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 princi-

ple” that is acceptable to economic theorists.

Binmore’s book *Just Playing: Game Theory and the Social Contract II* was written while he was ELSE director. This book presents his social contract theory in detail.

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). Dunbar and Pawlowski (*Proceedings of the Royal Society of London*, 1999) 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.

The second area of Dunbar’s focus has been on parental investment strategies. This has involved two major ongoing collaborative projects. One (with Berezkei) has focussed on sex-biased patterns of parental investment among Hungarian Gypsies. Berezkei and Dunbar (*Proceedings of the Royal Society of London*, 1997) 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. Re-

markably, they 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 and Lycett (*Proceedings of the Royal Society of London*, 2000) and has again focussed on sex-biased patterns of parental investment. The 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, Dunbar and colleagues have been able to show that parents seek to manipulate investment in offspring in such a way as to maximize lineage survival.

In another project (Annex A, Project 1.6), Dunbar has developed a set of four taxon-specific systems 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.

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 con-

troversial field. Investigating the reasons why this relationship holds, he has conducted two major empirical projects on social cognition. The first, conducted in collaboration with Barrett and Call (*Proceedings of the British Academy*, 1997), 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 and Kinderman, 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).

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 caused by degree of genetic relatedness. Dunbar and Plotkin have carried out experimental cross-cultural studies both in the UK and South Africa.

Seymour and Sozou (*ELSE Working Paper*, 2001) 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 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). The evolutionary model used is derived from the class of models developed by Seymour in related projects. 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* (2000) on evolutionary psychology was written and published within the funding period. 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.

Miller has also been prolific in disseminating his ideas in other media, and in his collaborative work on related issues.

Heyes' work on social cognition in primates has focussed on theory of mind and self-recognition. Her analy-

ses of the entire corpus of empirical work in these fields (*Behavioral & Brain Sciences*, 1998) have 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.

Heyes (see Annex A, Project 1.8) 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 has been tested against databases 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 finding that the capacity for imitation learning results from ontogenetic inflection 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.

(b) Learning Approaches

When we started ELSE we aimed at a better understanding of how agents learn in repeated decision problems and games and we have been pursuing a two-fold strategy in this research division, combining theoretical and empirical (mainly experimental) work.

Börgers, in joint work with Sarin, has explored the theory of reinforcement learning in decisions and games. Their 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 agents, with no strategic connection between the repetitions. Their 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 (*Journal of Economic Theory* 1997) showed how reinforcement learning models form a bridge between learning theory and evolutionary theory, thus establishing a close link to our research division on evolution. At a methodological level, their 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 (*International Economic Review* 2000) 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 also recently introduced an axiomatic approach to reinforcement learning. They show that all reinforcement

learning models with certain properties are closely related to evolutionary models.

Learning in dynamic problems has been theoretically investigated by Jehiel. In joint work with Samet he has extended models of reinforcement learning to dynamic games of perfect information. Postulating that moves rather than strategies are being reinforced, 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 (*Games and Economic Behavior* 1998, *Review of Economic Studies* 2001). He has developed a theory of learning in repeated games where, unlike in Börgers' work, stage games are strategically linked. Jehiel's goal is to model players who have limited foresight when playing such games. Applied to the repeated prisoners' dilemma his approach shows that it may be easier to sustain cooperation than to sustain defection when players have an intermediate horizon of foresight.

Another issue with which Jehiel has been concerned is 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. Jehiel has developed exploratory models of this form of learning. An application to the finitely repeated prisoner's dilemma shows that cooperation in the early phase of the game followed by defection towards the end may emerge for certain analogy classes.

How very naïve, low information learning can lead to cooperative outcomes in dilemma games is analysed in research undertaken by Huck, jointly with Normann and Oechssler.

They study a process where agents move along a grid and simply adjust their choice in one direction as long as this increases their payoff. In Huck, Normann, and Oechssler (*Journal of Theoretical Biology* 2002) they show that such a process yields collusive outcomes in finite dilemma games.

Throughout the seven-year period our theoretical research on learning was complemented by experimental investigations where the interaction between economists and psychologists has been very close. In experiments related to Börgers' theoretical work, Shanks, Tunney, and McCarthy (*Journal of Behavioral Decision Making* 2002) have extensively studied probability matching problems. Their results show that sufficiently large financial incentives and regular feedback greatly reduce the extent of sub-optimal behaviour that is frequently observed in this class of problems. The rate at which people learn to allocate all of their responses to the high probability alternative has been greatly increased in Shanks' experiments in comparison to previous experiments.

In experimental work dealing with dynamic choice problems, Shanks, also in collaboration with Tunney, has investigated melioration problems where it is optimal in the long run to choose one action while another action always yields higher payoffs in the short run. Shanks and Tunney (*Journal of Behavioral Decision Making* 2002) show that the extent to which subjects learn the optimal dynamic strategy depends on whether payoffs are stochastic or deterministic. They also show that learning is more efficient if subjects are allowed short periods to explore different strategies without any financial incentives.

Very recently, Huck and Jehiel have also turned to study Jehiel's theoretical approach to analogy-based learning in dynamic games by means of experiments. Their first results indicate the crucial role of feedback information on subjects' learning.

Our efforts to contribute to a better understanding of learning are complemented by two further research projects that have their roots in the psychology literature. Lober and Shanks (*Psychological Review* 2000) study learning about causation. They show how complex cognitive judgments relating to causation may be grounded in simple reinforcement learning mechanisms. Thus, this project bridges the gap between elementary learning and higher-level cognition.

Whereas the projects described so far investigate how individuals learn from their own experience, Heyes and Ray have undertaken a major project about learning through imitation. In both, theoretical and experimental work, they elucidate the role of imitation learning in social evolution, and the cognitive mechanisms mediating imitation in human and nonhuman animals. Heyes and Ray (e.g., *Advances in the Study of Behavior* 2000) have developed a model of Associative Sequence Learning (ASL) which implies that imitation only makes a distinctive contribution to social evolution when it is combined with higher-order intentionality. The ASL model has been adopted by researchers in AI and successfully implemented in robotic systems. Heyes (*Trends in Cognitive Sciences* 2001) has also tested the model in experiments where it was, for example, shown that birds are capable of motor as well as vocal imitation. On a methodological level, these experiments have established a procedure of testing for imitation in animals that

has, by now, become standard among psychologists.

(c) Behavioral Economics

This research division integrates a number of theoretical and experimental based projects developed to enhance our understanding of decision making, learning, memory, forecasting, discounting, and motivation, anchored in notions of bounded rationality. The theoretical work currently focuses on the optimal behaviour of agents with imperfect recall. Two projects headed by Börgers investigate optimal learning by an agent with imperfect recall and the interaction among agents with imperfect recall. In the latter of the two, Börgers has demonstrated that physical order is a useful metaphor for the shared memory of a society and has shown that there are equilibria with the optimal amount of physical order as well as equilibria with too much, or too little order.

A second memory based experimental project by Heyes, McCarthy and Plotkin examines how and why social interaction during recall of information leads to reduction in the amount remembered and to normalisation of content.

Another avenue of decision making research which has been explored by Newell and Shanks concerns the claim made by Gigerenzer and Selten that decision makers have access to a range of heuristics, these achieve near-optimal outcomes without employing optimal decision algorithms. Newell and Shanks (*Journal of Experimental Psychology*, in press) have undertaken experimental evaluations of one such proposed heuristic: Take-The-Best, thought to be used in a range of choice situations. The goal of this research

has been to identify the conditions under which people adopt this heuristic and those in which they employ more normatively appropriate strategies.

Rey's research project considers the implications of inequity aversion: Individuals dislike outcomes where they themselves are much worse off than other individuals, but they also avoid situations in which they themselves are much better off than others, on incentives proposed by employers. Rey has demonstrated that an employer uses the phenomenon of inequity aversion among employees to his own advantage. Presently, the results from this research project do not support claims in the literature that inequity aversion leads to incomplete incentive contracts.

Performance-related-pay has been introduced into a number of areas of the public sector (e.g. the Inland Revenue, NHS, schools). Leaver explores the effects this scheme has on the motivation of the workforce. Leaver aims to establish conditions under which explicit incentives can create perverse effort effects. Public sector unions remain opposed to performance-related-pay schemes, claiming they demotivate an already motivated workforce. Moreover, current work suggests that intrinsic rewards such as self-esteem play an important role in the public sector. The project investigates the interaction between these motives and the informational content of extrinsic, performance-contingent rewards.

Swierzbinski heads two projects that focus on the valuation of environmental resources: the legal, academic, and regulatory developments pertaining to the appraisal of environmental resources, services, and ecosystems. The first project is based on a small contingent valuation survey conducted

by Murato in the summer of 1996. The survey investigated responses to different management policies concerning the endangered black rhinoceros. Swierzbinski and Murato identified differences in the time preferences of respondents. A large subset of the survey appeared to be best described by something like hyperbolic discounting.

In a second project, Swierzbinski has investigated framing effects in contingent valuation. Swierzbinski compared responses to different versions of a questionnaire based on the famous Al-saka-Exon Valdez study. The results from each version of the questionnaire were used to assess the extent to which the starting point and order in which hypothetical payments for goods were offered affect a respondent's reported willingness to pay. These comparisons revealed large differences in the results from different versions of the questionnaire used in that study. The presence of such clear framing effects has important implications for environmental valuation and is an important issue for policy makers.

(d) Mechanism Design

The main focus of our research on mechanism design throughout the last seven years has been on auctions. Much of this research has had an immediate impact on non-academic users. The most prominent example of this is the design of the British UMTS auction, summarised in Binmore and Klemperer (*Economic Journal* 2002). We have also been involved in a wide variety of consultancy projects elaborated in Annex A.

This emphasis on auctions is also reflected in the research projects laid out in Appendix A. Six of the nine projects deal with auctions, of which four are

theoretical and two are empirical (covering both laboratory and field evidence).

At the forefront of our theoretical research is Jehiel's work on auctions with externalities. Jehiel and Moldovanu (*Review of Economic Studies* 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. Jehiel and Moldovanu (*RAND Journal of Economics* 2000) observe that entry fees and reserve prices in one-object auctions have different qualitative implications in the presence of externalities. Jehiel and Moldovanu (*Econometrica* 2001) analyse a mechanism design problem with interdependent values, multi-dimensional signals and various social alternatives, where agents possess private information that is relevant to other agents' valuations. They show that, irrespective of the need for participation constraints, it is generically impossible to induce an efficient outcome. This finding is in sharp contrast with the standard Vickery, Clarke and Groves result. Finally, Compte and Jehiel (*Econometrica* 2002) show that increasing the number of bidders improves social efficiency in a private setting but not with interdependent values and asymmetric bidders.

Collusion in auctions has been a topic we have been pursuing since 1995. Caillaud and Jehiel (*RAND Journal of Economics* 1998) show that the presence of externalities may make collusion among privately informed bidders more difficult. Agastya, Albano, and Larson have all been involved in related projects. Agastya in joint work with Daripa has shown that bidding rings need not always lower the expected revenue of the seller, suggesting

that revenue maximising sellers may have good reasons to allow bidding rings. Larson has explored the impact of permitting groups of bidders to pool their information and submit a single joint bid in second price common value auctions. He identifies conditions under which the seller does best to forbid group bids, as well as exploring situations in which some group bidding might be optimal for the seller. Finally, Albano, in joint work with Germano and Lovo, focus on the phenomenon of collusion in multi-object ascending auctions (e.g., the U.S. FCC auctions).

Multi-unit auctions have also been tackled by Binmore, Börgers, and Swierzbinski while undertaking advisory projects. Two surveys have resulted from this research: Binmore and Swierzbinski (*Review of Economic Design* 2000) and Börgers and Swierzbinski (Reports about Commissioned Research, 2002). One of the main issues discussed in these papers is the comparison between uniform and discriminatory price auctions. Further issues in the theory of auctions have been studied by Albano, Larson, and Matros.

Empirical analyses of behaviour in auctions have also been on our agenda from early on. Börgers and Dustmann have been examining bidding behaviour in the UMTS licensing procedures in all the member states of the European Union. Their study of bids in the UK UMTS auction has revealed behaviour that is difficult to rationalise. The most significant anomaly was 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). This finding 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 is true, auction formats that make this type of strategy impossible may be advantageous.

Experimental studies have complemented our work on theory, design and field data. We have undertaken experimental studies of a wide variety of auction formats. Most of these experiments have explored issues raised by our advisory work on auctions. Some of the results have had to remain confidential because of the consultancy contracts under which they were carried out, including the experiments carried out for the UK UMTS auctions. In addition, 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.

Our remaining three projects in mechanism design are comparatively young. They have been started since 2000 and will all continue into 2003.

Albano and Leaver have studied work incentives in the public sector, developing a dynamic model of sector choice. Their aim is to investigate how 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.

Börger has used a mechanism design approach to investigate the advantages and disadvantages of alternative voting systems. As a first step, he has asked how participation costs affect the optimal design of voting procedures. In a simple setting, with private values and only two alternatives, voluntary major-

ity voting results in equilibrium participation rates that are too high relative to the social optimum. Further analysis asks investigates when voting in a committee dominate voluntary majority voting.

Finally, Börger, Larson, Salmons, and Swierzbinski develop policy-relevant insights into the design of auction and markets for environmental permits. Some of this research is carried out under external research contracts (with the Radiocommunications Agency, NERA, and the Environment Agency).

(e) Automated Trading and Negotiation

In two closely related projects we have studied e-commerce and price formation and e-commerce and negotiations. A key aim was to understand the impact of electronic trading arrangements on the behaviour of firms and consumers, and the implications for market outcomes.

Ulph and Vulkan have analysed whether e-commerce gives firms scope to offer consumers customised products at customised prices as is often argued. They first consider the case where firms can customise prices but not products and 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. Unless there is a very high degree of consumer loyalty the second effect dominates the first. Thus, even if e-commerce makes discrimination feasible, it still may not be adopted.

In a second study, Ulph and Vulkan 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 have conducted research on recent developments in electronic trading arrangements. One of the central aims of their analysis is to determine whether electronic data interchange (EDI) will result in a competitive market outcome (via the elimination of search costs for consumers) or implicit collusion (via improved monitoring of other producers). First results cast doubt on the conventional wisdom that a lower price equilibrium will always result.

The worldwide web gives rise to the possibility of automated negotiations. In an EPSRC co-funded project Binmore, Vulkan and co-authors have applied game theoretic techniques to the design of negotiation algorithms to be used by autonomous software agents in electronic commerce. Such algorithms are important whenever negotiations need to be conducted very quickly and frequently (e.g. negotiations between large communications users and telecommunications network providers over required bandwidth and price).

Binmore and Vulkan (*Netonomics* 1999) and Vulkan (*Economic Journal*, *Wirtschaftspolitische Blätter* 1999) develop a general classification scheme for automated negotiations in e-commerce.

In joint work with Priest, Vulkan provided a specification for an on-line algorithm for trading in communication bandwidth. In research with Sandholm, Vulkan focuses on deadlines in automated negotiations. 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 Price-line.com).

Finally, Vulkan (*Games and Economic Behavior*, 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.

The aforementioned projects will soon be concluded. We have, however, started a new project in this Research Division on the role of trust for anonymous Internet transactions. The project will use theoretical, experimental and empirical research methods and will provide links to our divisions on Learning and Behavioural Economics.

Joffe, in joint work with Rogers, investigates 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 and Tyran studies the evolution of trust in a laboratory environment. Their focus is on which institutions help to establish trust and trustworthiness. 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.

(f) Industrial Organisation

Industrial Organization has been a division of ELSE from the inception of the centre. The program of the division forms a natural outlet for some of the more applied aspects of ELSE's fundamental research. The research undertaken in this division encompasses applications of learning and behavioural economics. However the division has also contributed to subjects more central to industrial organisation such as the study of pricing or innovation. Increasingly the theoretical work undertaken in this division is being subjected to empirical verification through experiments or econometric techniques.

One initial focus of our research in Industrial Organisation has been on analysing investment in innovation and its effects on welfare. This effort has continued over the entire seven-year period. Recently it has become somewhat less central to our agenda as David Ulph has left ELSE.

Ulph's research on innovation (now continued by von Graevenitz) concentrated on research collaboration by firms in Research Joint Ventures. The motivation was to improve our understanding of firms that co-operation on R&D and simultaneously compete in product markets. This effort was complemented by research into the effect

institutions have on firms' choices with respect to innovation. Considerable progress has been made in both projects. In particular the co-ordination of research activities through RJV formation was studied in a wide class of models. This has led to insights regarding possible anti-competitive abuses of RJV formation (Katsoulacos and Ulph, *Journal of Industrial Economics*, 1998). Furthermore the effect of competition on the performance of RJVs has been examined theoretically. It was shown that the formation of an RJV is particularly beneficial to society in less competitive markets (von Graevenitz, Does competition affect how firms should collaborate on R&D?, working paper). In a co-funded project the theory of RJVs has been applied to environmental issues (Katsoulacos, Ulph, and Ulph, book chapter, 1999). Here it was shown that RJVs perform well when damages are low, but poorly when damages are high.

In our research on institutions, one focus was on how unionisation impacts on firms' research efforts. Ulph and Ulph (*Scandinavian Journal of Economics*, 2001) developed a theoretical model showing that increasing unionisation does not necessarily result in a reduction of R&D investment. Empirical evidence on this matter has been provided in Menezes-Filho, Ulph, and van Reenen (*European Economic Review*, 1998). Another focus was on the mechanisms through which innovation systems affect economic growth. Here a key variable is the degree of knowledge diffusion. Encaoua and Ulph (working paper, 2000) model the effects of increased competition in product markets on the incentives to invest in R&D. Their model shows that markets for technology licenses are crucial if firms in less developed countries are to generate more growth.

The second main focus of our IO research has been on the role of information in markets. Ottaviani and his co-authors studied the value of public and private information in monopoly (Ottaviani and Pratt, *Econometrica*, 2001; Ottaviani and Moscarini, *Journal of Economic Theory*, 2001). In a new and ongoing project Albano studies the role of comparative advertising. Albano has also been working on the role of quality certification in an uncertain environment. Albano and Lizzeri (*International Economic Review*, 2001) demonstrate the beneficial effects of having a certification intermediary in markets. Albano continues this research with Newman and Sahuguet.

From 1998 to 2001 we pursued two different projects on price and transparency and price diffusion. Ulph and Vaughan wrote a report for the European Commission on the implications of the single European currency for competition and for consumers. The three main findings were (a) that by making price comparisons between products easier, competition may be enhanced; (b) that by making prices more observable for competitors, implicit collusion may be facilitated, and thus competition reduced; and (c) that the arbitrage possibilities between markets may be increased, which is of benefit to the consumer. In related theoretical work, Hopkins and Seymour (*International Economic Review*, forthcoming) studied under which conditions different prices might be obtained when sellers adjust their prices adaptively. With consumer behaviour fixed, they found that convergence to a dispersed price equilibrium is possible. However, once consumer learning is introduced, the monopoly outcome, first found by Diamond, is the only stable equilibrium.

An ongoing item on our research agenda is the analysis of incentives for experts, forecasters and, since 2001, also for regulators. Ottaviani and Garidel-Thoron (The Economics of Advice, working paper) formulate a simple model of advice that can be useful to guide the regulation of the financial retail industry. Ottaviani and Sørensen (Rank-Order and Forecasting Contests; Professional Advice: The Theory of Reputational Cheap Talk, working papers) develop and compare two theories of strategic behavior of professional forecasters. The first theory posits that forecasters compete in a *forecasting contest* with pre-specified rules. In equilibrium of a winner-take-all contest, forecasts are excessively differentiated. According to the alternative *reputational cheap talk* theory, forecasters aim at convincing the market that they are well informed. If the market has naive views on forecasters' behavior, forecasts are biased toward the prior mean. Otherwise, equilibrium forecasts are unbiased but imprecise.

Relatively new on our agenda is experimental research in IO. This became a new focus when Huck joined ELSE in September 2001. His research on behaviour in oligopolistic markets is closely linked to our research divisions on Learning and Behavioural Economics. His work on *inequity aversion* may serve as an example here: while economic theorists usually assume that agents maximize profits, there is an ongoing research program in Behavioural Economics that investigates aversion to inequity. In a study of Stackelberg markets (Huck, Müller and Normann, *Economic Journal* 2001) it is shown that second movers' reaction functions are considerably flatter than theory predicts. This is consistent with inequity aversion. Huck, Müller, and Normann (*Games and Economic Behavior*, 2002) study a model that pre-

dicts 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 which is consistent with inequity aversion.

Huck has also conducted experiments on mergers in Cournot markets, and is now pursuing a theoretical project on mergers. There the focus is on how mergers might be profitable even if there are no cost advantages. In a working paper with Konrad and Müller (Profitable Horizontal Mergers Without Cost Advantages: the Role of Internal Organization, Information and Market Structure) it is shown that mergers might create commitment advantages rendering a merger profitable, provided that the organizational structure of the merged firm is appropriately modelled. Finally, Huck and Konrad (Merger Profitability and Trade Policy, working paper) study how mergers might be profitable (and welfare enhancing) in the presence of strategic trade. Their findings can explain why the Boeing-McDonnell Douglas merger was opposed by European but not by US competition authorities.

2.4. Academic Dissemination of ELSE's work

Several of the objectives of ELSE, as agreed with the ESRC, require us to disseminate the results of our research within the academic community. Thus, as indicated in Section 1.2 above, we are required to “develop and implement a dissemination and publicity strategy for the centre to bring new findings to the attention of the academic community”, and to “publish significant theoretical findings in refereed journals, books, and reports”. We are also expected “to advance method-

ology and substantive knowledge in the area of study, by such means as research seminars for the wider academic community and training in research methods”.

The publication record of ELSE is very substantial. Annex B lists about 20 books published by ELSE researchers, about 100 contributions to books, and more than 200 refereed journal articles in refereed journals. ELSE researchers are guided by ELSE management to submit their work to the highest ranked international journals and publishers. This strategy has borne fruit.

We have also established a number of conferences and seminar series that are open to researchers from outside the research centre. Examples are the ELSE research seminars that have often been a forum for discussion of evolutionary psychology for interested academics from throughout the UK. At the University of Liverpool we run a fortnightly workshop on evolutionary psychology that attracts about 40 researchers from the Northwest of England.

For four years ELSE has supported the “ESRC Research Seminars in Game Theory”. These were partially funded by an ESRC conference grant, jointly held by Murali Agastya, Tilman Börgers and Martin Cripps, but additional funding as well as administrative support were provided by ELSE. These seminars operated from 1997 until 2000. Three meetings per year took place. Two of these meetings were one-day workshops, whereas the third meeting each year was a residential weekend conference. For each meeting of this seminar group at least one well known overseas speaker, often from the United States, was invited. Examples of researchers who spoke in these seminars are: Larry Ausubel, Sergiu

Hart, Michihiro Kandori, Vijay Krishna, and Roger Myerson.

The seminars were addressed primarily at game theorists throughout the United Kingdom. They were attended by a regular group of about 30 to 40 participants. By all accounts these seminars were much appreciated, and constituted an important opportunity for UK researchers to update their knowledge about research progress in important core areas of ELSE's research.

Another important part of the academic dissemination of our work is our pages on the worldwide web (<http://else.econ.ucl.ac.uk/>). New papers by ELSE Research Fellows are made available on these pages for download. The web pages also contain a general introduction to ELSE's research, contact details of ELSE researchers, and the details of events and seminars at ELSE.

2.5. Academic Collaborations

The objectives of ELSE, as explained in Section 1.2, include that we seek "to establish ELSE as a focus of collaboration within the scientific community". We have done so in several ways. First, and most importantly, most researchers at ELSE conduct their research in collaboration with researchers from outside of ELSE. This is documented in detail in Annex A. Examples of prominent collaborations are Binmore's work with Samuelson from the University of Wisconsin on stochastic evolution, Binmore's work with Klemperer from Oxford University on spectrum auctions, Börgers' work with Sarin from Texas A&M University on Learning Theory, Jehiel's work with Moldvoanu from the University of Mannheim on auctions,

and Agastya's work with Daripa from Birkbeck College on collusion in auctions.

It is also worth mentioning that not all ELSE research fellows are based at UCL. Three researchers who were initially based at UCL have moved to other universities, but have maintained their link with ELSE by staying on as Research Fellows. Dunbar is now at the University of Liverpool, Vulkan is at the Saïd Business School in Oxford, and Ottaviani is at London Business School.

We have also sought to develop institutional relations with other research centres, both in the United Kingdom and abroad. For example, in the United Kingdom we have started to develop joint empirical projects with Cemmap, a centre for quantitative research based at the Institute for Fiscal Studies and University College London. Europe-wide we are part of several networks of research groups. Several collaborations have been conducted in the framework of European Community funding programmes. The most prominent example is the project on "Growth, Inequality and Training" co-ordinated by Ulph.

We plan to continue this work. We have recently participated in two European networks that have submitted expressions of interest under the European Union's Framework 6 programme. The preparatory work for one of these submissions was co-ordinated by David Ulph, and it was funded through a small grant that the ESRC awarded to us specifically for this purpose.

2.6 Training of Postgraduate Research Students

As explained in Section 1.2, one of the objectives of ELSE is “to engage actively in the training of postgraduate research students.” A detailed account of doctoral students trained by ELSE research staff is given in Annex E4. This Annex lists about 70 doctoral students.

All PhD students are registered in one of the academic departments involved in ELSE, and their supervision arrangements are determined by college rules and by the rules of their respective departments. The departments are ESRC recognized departments for doctoral training. Their PhD programmes involve a programme of course work and independent research. Doctoral students are often jointly supervised by several members of ELSE.

These students have benefited from ELSE in a variety of ways. ELSE has enabled its senior researchers to find the time needed to develop their own research, and fruitfully to involve research students in their own research work.

ELSE’s seminars and the informal interaction with ELSE colleagues have shaped the way our graduate students approach their research. Our graduate students often take away from their time at ELSE an interdisciplinary perspective on their work. Our graduate students have also benefited significantly from the close contact with applications of our research.

At a relatively mundane level, ELSE has often been able to offer these students better office accommodation and research facilities, for example computer facilities, than the departments involved in ELSE would normally have been able to.

Many of the doctoral students have moved into academic positions at universities such as the Universities of Edinburgh, Alicante, Bristol, Southampton, or Malaga. Our students’ ability to take up these positions indicates the respect that other universities have for the research training that we provide. Other students benefit from the close interaction with applications of our research and move into private or public sector positions after completion of their PhD.

3. Other Objectives

3.1 Links with Non-Academic Users and Impact on Policy and Practice

One of ELSE's objectives is "to establish ELSE as a focus of collaboration with potential users of its scientific programme, both nationally and internationally." The agreement between UCL and the ESRC also specifies that ELSE should "seek to develop links with users through seeking their advice on the research programme, through publications, seminars and conferences, through teaching programmes and other means". Indeed, it is part of current ESRC policy to attach much importance to the links between ESRC research centres and users.

ELSE has taken an outcome-focused approach to its interactions with non-academic users. By this we mean that we measure our performance by the impact that we have on practical decision-making. Without doubt, ELSE's performance in this respect is excellent.

In order to achieve an impact on policy, ELSE's strategy has been to seek primarily advisory work, where concrete policy or business decisions needed to be prepared, and the advice of ELSE researchers served as input into the decision making.

The list of advisory projects in which ELSE staff have engaged is very long. Indeed, for a while the volume of ELSE's advisory work was so large, that it was necessary to set up a separate company, ELSECo, to handle this work. ELSECo had a business manager, Tony Curzon Price, whose main responsibility was to handle ELSE's

contacts with government and business institutions.

Much of the advisory work of ELSE was in the area of auction design. The peak of our advisory work was reached in the years 2000 and 2001 when many European and Asian countries used auctions to sell licenses for the operation of third generation mobile telephone networks. This wave of auctions has now largely been completed, and ELSE's advisory work is now easier to manage. For this reason, ELSECo is now being wound down as too cumbersome administratively in the new circumstances. An independent consulting company will continue to exist. There will be limited involvement of some ELSE staff in this company.

The details of our advisory work are listed in Annex B12. Here, we provide brief summaries.

(a) Advice on Spectrum Auctions

ELSE's work in the area of auction design was motivated by the auctions of spectrum licenses to mobile phone companies which occurred in the United States in the mid 1990s, and in which academic game theorists were strongly involved as advisors to government and industry. These auctions made it natural for us to seek involvement in the same policy area in the United Kingdom.

We established contacts with relevant policy makers at a conference that we organized in December 1996. The Radiocommunications Agency tendered for advice regarding the auction of mobile telephone licenses in 1997, and the contract was awarded to ELSE in November of that year. The ELSE team advising on the auctions was led by Ken Binmore, and included Tilman

Börger, Philippe Jehiel, and Joe Swierzbinski. We also included outside advisors in our team. These were Paul Klemperer from the University of Oxford and Jeremy Bulow from Stanford University. Klemperer is one of Europe's leading auction theorists, and Bulow is a leading auction theorists as well as a frequent collaborator of Klemperer.

In bidding for the Radiocommunications Agency's contract our primary goal was not to raise funds, but to gain experience in policy advice, and to build up a relevant reputation. Ex post, this strategy turned out to be very clearly the correct choice.

From November 1997 onwards we participated in a sequence of meetings with government-organized groups, some of which involved industry representatives as well. We offered several advisory papers for the government. These papers reflected theoretical research as well as experimental results. Most of the papers that we produced for the government are covered by a confidentiality agreement with the government, and can therefore not be cited here. However, the broad structure of our advice is publicly documented.

Advice was offered in two steps. Initially, the UK government thought that the number of third generation mobile telephony licenses that it could auction was equal to four. This number is significant because four is also the number of incumbent operators in the second-generation mobile telephony market in the UK. Thus it might have appeared to be a foregone conclusion that the four incumbent operators would also win the four new licenses. But one of the UK government's goals was to encourage interest from outsiders in the auction. ELSE therefore advised to

conduct a so-called Anglo-Dutch auction, in which an open, multi-round auction is followed by a final, sealed-bid stage. This advice was based on theoretical arguments developed by Klemperer, and the UK government accepted this advice.

However, late in 1998 it emerged that the UK government was actually able to offer five licenses for sale. In this situation, the problem of encouraging participation in the auction became a less severe one, and ELSE recommended an open, ascending auction in the style conducted by the FCC in earlier years. Again, the UK government adopted this advice.

ELSE became involved in a number of detailed discussions regarding the auction rules. ELSE was also involved in decisions about who was allowed to participate in the auction. A particularly pressing problem arose when a link emerged between two supposedly independent bidders, Vodafone and Orange. The link resulted from Vodafone's takeover of Mannesmann, which, at that stage, owned Orange. The resolution of this issue was that Vodafone entered a commitment to dispose of Orange after the auction, and to erect Chinese walls between its own bidding team and that of Orange. Both companies were then allowed to bid. ELSE was actively involved in the discussions that lead to this resolution of the issue.

The auction took place in March and April 2000. 13 companies entered the auction. The auction lasted 150 rounds, and ultimately raised £22.5 billion, a very significant contribution to the UK government's income.

ELSE's participation in this auction lead to a number of similar follow-up projects. While the UK auction was the

first auction in Europe of spectrum licenses for third generation mobile telephony, a number of other European countries subsequently decided to conduct such auctions as well. As already mentioned, we set up a formal company, ELSECO, to bid for these contracts, and our bids were often joint bids with commercial partners, among whom Rothschild's Bank played the most prominent role.

The other European governments that we advised on spectrum auctions were the governments of Belgium, Greece and Denmark. The Belgian government adopted a format similar to the one in the UK. The other two governments adopted auction formats with a strong sealed-bid element, and the advice to adopt these formats was based on reasoning similar to that which underpinned the initial advice to the UK government to adopt an Anglo-Dutch auction.

The auctions in Belgium, Greece and Denmark took place in a much-changed economic atmosphere. However, in particular the auctions in Greece and Denmark were regarded as reasonably successful in terms of revenue given that, rationally, expectations had diminished at this stage.

Other advice which ELSE has offered regarding third generation spectrum auctions is advice to the governments of Hong Kong, Israel, and Latvia regarding the auction of mobile phone licenses, and advice to a parliamentary investigation of the controversial license auction in the Netherlands.

The impact of the spectrum auctions on the mobile telephone industry, and on the share prices of telecom companies, has been much discussed. This is not the place to join this discussion, but we have commented in Subsection

2.3 above on activities that we have undertaken to evaluate the license auctions.

(b) Advisory Work in Other Areas

The very public success of ELSE's work on spectrum licenses has also lead to a number of advisory projects in areas other than the communications industry. Many of these projects are in the general area of auctions.

Next to the telephone industry it is perhaps the energy sector in which interest in auction mechanisms is greatest. In the United Kingdom auctions are, in particular, quite common in the gas industry. We have advised Transco, the monopolist operator of the gas transmission network in the United Kingdom, about auctions of gas storage rights. We are at the moment advising the Office of Gas and Electricity Markets, that is the regulator of the energy industry, regarding the auctions of long-term entry capacity into the gas transmission network. This work is less prominent in the media than the work on the mobile telephone licenses, but we regard it very important nonetheless. Our advice in this area has direct policy impact.

There is much interest in auctions also in the media sector. We have advised on the auction of live transmission rights for premier league football, and we are continuing to develop contacts in this area.

Auctions are of particular interest to game theorists because they constitute a context in which the "rules of the game" are particularly well controlled. Another set of circumstances in which the "rules of the game" can be controlled are organized markets, such as stock exchanges. We have sought to

become involved in this area, too. Most of our work in this area has, however, so far the nature of contract research rather than advisory work. This will therefore be reported in Sub-section 3.4 below.

We have also offered advice in the general area of industrial organisation and competition policy. ELSE researchers have been involved in some competition cases, such as the proposed Airtours/First Choice merger, and the proposed BSKyB takeover of Manchester United.

(c) Difficulties Arising from Advisory Work

That ELSE could undertake such a large amount of advisory work is, of course, primarily positive. However, the unexpected extent of this work has also lead to several problems.

- **Resources:** Due to the large number of projects undertaken, advisory work has taken a much larger than expected proportion of the most important resource which ELSE has: researchers' time. On the other hand, the projects that we have undertaken were not primarily meant to raise funds, and therefore the monies received from these projects have not been enough to hire sufficient personnel to reduce researchers' time commitment.

We have recognized this as a difficulty, but have decided initially to continue with our advisory work because the spectrum auctions seemed to constitute a historic opportunity that would not repeat. However, as most of the spectrum auctions have now been concluded, our policy is to reduce the workload resulting from advisory projects so that researchers can concen-

trate again primarily on their fundamental research.

- **Organizational Structure:** For several years we have decided to operate through an independent company, ELSECo. The purpose of setting up such a company was twofold. Firstly, we wanted to provide the legal protection offered by a limited company to the researchers who were undertaking advisory work. Secondly, we wanted to build up a brand reputation in the field. ELSECo has been very successful in achieving both aims. However, this organizational framework is not without costs. ELSECo has to be financially independent of both the ESRC and the college. To achieve this, it has to have a certain minimum amount of business. In early 2002 the ELSE executive committee decided that the amount of consultancy activity that we would have to undertake to make ELSECo financially viable was no longer compatible with our commitment to fundamental research. ELSECo is being wound up, and a successor company will involve ELSE staff to only a very limited extent.

- **Independence:** An important goal for ELSE is to stay in long-term contact with non-academic users. At the same time, however, ELSE seeks to maintain its academic freedom. In plain words, ELSE needs to be free to make public statements of which the non-academic users may not approve. We believe that both objectives can be achieved if some care is exercised in selecting the advisory projects in which ELSE gets involved.

- **Relation with Fundamental Research:** In consultancy work there is always a temptation to overstate how much is known from academic research. An institution like ELSE, which is funded primarily by govern-

ment money, must use the freedom provided by this funding base to state clearly what is, and what is not known. In many of the areas in which we offer advice, for example in the field of multi-unit auctions, theoretical knowledge is actually quite limited. In other areas, such as single unit auctions, the theory is well developed, but the empirical basis for the theory is still rather slim. ELSE management encourages all ELSE researchers involved in advisory work to be completely frank about the limitations of academic knowledge.

A second issue concerning the link between our advisory work and our fundamental research is that the advisory work is linked to only one part of our fundamental research. Other areas in which we do fundamental research, in particular evolutionary and learning approaches to human behaviour, have generated much less consultancy work.

To some extent, it is not surprising that areas such as evolution and learning do not yield to as much advisory work as research on auctions and mechanism design. Evolution and learning are much more “blue sky” research topics than auctions and mechanisms. However, it may also be that the success of our advisory work in the area of auction has lowered our incentives to look for applications of other areas of our work. As our commitment to advisory work in the area of auctions diminishes, we expect that we shall become more active in seeking applications for other parts of our activities.

• **Feedback of advisory work into research:** ELSE is seeking to establish a two-way dialogue between our advisory work and our fundamental research. Because such a large proportion of our resources have been committed to advisory work, we have not yet been able to fully develop this dialogue. However, we intend to do so

logue. However, we intend to do so in the future.

As most of our advisory work so far has concerned auctions, this is the area in which we anticipate the largest amount of research activity inspired by advisory work. Examples of research problems raised by our advisory work are the following: evaluation of the empirical evidence resulting from the recent spectrum auctions; theory of auctions when bidders are employees of companies which evaluate them using relative performance criteria; collusion in auctions; theory of multi-unit auctions.

3.2 Contract Research

In addition to advisory work, which is directly linked to policy or business decisions, ELSE has also undertaken a number of projects of advisory work where there is no decision directly linked to our work, but where our work will form in the long term an input into some policy or business decision.

Our contract research has mostly concerned two areas: firstly, auctions and mechanism design; secondly, Industrial Organisation.

In the area of auctions and mechanism design we have commissioned research for the Environment Agency regarding the use of market-based instruments in environmental policy. This is a long-term project that seems highly appropriate to ELSE as it diversifies applications of its work away from telecommunications. We have also conducted commissioned research for the Dutch government concerning the use of auctions in a variety of areas of government policy. We are also currently conducting a joint project with the

consulting company NERA about secondary trading in spectrum licenses.

In the area of industrial organisation our work has primarily been for the authorities involved in competition policy in the UK, and for the European Community. We have reported to the United Kingdom's Office for Fair Trading on a variety of ways in which this office's policies affect distributional issues.

As far as the European Commission is concerned, we have reported on the economics of globalisation, and also on the effect of price transparency on market equilibria.

We have also undertaken contract research in some other areas. In particular, we have advised on reform of the National Health Service. Binmore was a member of a commission that published a report about possible reforms of the National Health Services. Binmore and Ulph have also undertaken government-commissioned research about incentives in the UK's National Health Service. Finally, Ulph and Vaughan have undertaken work for the Industrial Society on Public-Private Partnerships and the London Underground. Ulph and Curzon-Price have worked for the UK Treasury on contract design issues in the context of the "private finance initiative".

Contract research has stimulated further fundamental research. For example, work for the National Health Service, and interaction with the Industrial Society, has suggested further research on motivation and incentives. The interaction with the Environment Agency has made us more aware of the importance of additional research on multi-unit auctions.

3.3 Non-Academic Dissemination

ELSE's objectives, as agreed with the ESRC, require us "to develop and implement a dissemination and publicity strategy for the Centre to bring new findings to the attention of non-academic users, and to contribute to debates on public policy". We are also expected to publish "articles for a more general readership". As mentioned in subsection 3.1, we are also "seeking to develop links with users seminars, conferences, and teaching programmes."

ELSE's work on spectrum auction has lead to a burst of publicity that probably by far exceeds the amount of publicity typically received by ESRC research centres. Print - and broadcast media have reported about ELSE's involvement in the auctions. ELSE's Annual Report for the year 1999/2000 contained 55 pages of cuttings from UK print media alone referring to the UK spectrum auction. Significant coverage was given to ELSE's work also in the broadcast media, and in the print- and broadcast media abroad, whenever ELSE was involved in auction design.

Although coverage of our advisory work constitutes such a large proportion of the media coverage of ELSE's work, we should emphasize that we do not seek actively such media coverage. Our experience is that advisory work is best done quietly, and often confidentially, and that all media coverage should be initiated by the person or institution who is being advised rather than the advisor.

Another way in which ELSE's work has been prominent in the media is generally accessible science writing on evolution. Examples of important publications in this area are Dunbar's work on the evolution of language, Heyes'

book on the evolution of cognition, Miller's book on sexual evolution, or Plotkin's books on evolution and the mind. Binmore's books on evolution and moral philosophy require a reader that is more open to formal mathematical arguments than the books just listed but they are also directed to an interdisciplinary readership.

Several of ELSE's researchers are prominently involved in the public dissemination of science through media such as TV and radio. Robin Dunbar, Cecilia Heyes and Geoffrey Miller have all regularly appeared in these media. We document this in detail in Annex B10.

The record in Annex B10 is very impressive, and is all the more impressive as it has come about without the need to put a significant proportion of ELSE's resources into courting media. Some researchers at ELSE are particularly gifted at communicating with general audiences, and their contacts in this area are sufficient to generate extensive coverage of ELSE's work.

Another way in which we reach general audiences is through the ELSE pages on the worldwide web (<http://else.econ.ucl.ac.uk/>). Our pages are maintained by Chris Tomlinson. They give a full picture of our work. The main function of the internet pages is to make our work accessible to the academic community, but occasionally we are approached by others who have become aware of us through the web pages.

4. Management

4.1 Management Structure

ELSE is managed by its director, its administrative deputy director, its scientific deputy director, its executive committee, the heads of the research divisions, the advisory committee, and by the centre's administrative staff. In this subsection we shall explain the roles of the different positions in ELSE's management, and we shall recount who in the history of the centre has held these positions. In the next subsection we shall focus on management functions, and we shall explain how these functions are performed and by whom.

The most senior member of the management team of ELSE is the *director*. The *director's* task is to provide scientific leadership to the centre, to ensure that the centre achieves its objectives, and to manage jointly with other ELSE staff the finances of the centre.

From 1995 until 2001 the director of ELSE was Ken Binmore. Binmore is a professor of economics at University College London. Binmore stood down from his position as director of ELSE in 2001 because he approached retirement, and because he wanted to use the last two years before retirement for extended periods of leave from UCL. He spent the first leave period at the Institute for Advanced Studies in Princeton, and he will spend the second leave period at the California Institute of Technology. Binmore remains involved with ELSE's research, and we anticipate that this will continue beyond his retirement from his university position.

From 2001 until 2002 Tilman Börgers was the acting director of ELSE. Following the ESRC's approval of his ap-

pointment, Tilman Börgers became the new director of ELSE in 2002. Börgers is a professor of economics at University College London. He has been a member of ELSE's management team since ELSE was established in 1995.

The *administrative deputy director* is responsible for the day-to-day running of the centre, for the supervision of the administrative staff, and for the management of ELSE's finances.

The position of an administrative deputy director was only created very recently, in 2002. From 1995 until 2002 ELSE had an "executive director" instead of an administrative deputy director. From 1995 until 1997 the executive director of ELSE was Ray Jackson, an operations research professor at UCL. Ray Jackson retired because of ill health. From 1997 until 2001 the executive director of ELSE was David Ulph, an economics professor at UCL. David Ulph resigned in the summer of 2001 to take up a position as director of research at the Inland Revenue.

After Ulph's departure Richard Vaughan became acting executive director. It was then decided to rename the position as that of an "administrative deputy director", and to introduce in addition a scientific deputy director. Richard Vaughan was then appointed administrative deputy director. Vaughan is a senior lecturer in economics at University College London. He has been a member of ELSE's management team since ELSE was established in 1995. He has been deputy executive director of ELSE in the past.

The *scientific deputy director* works with the director to provide scientific leadership to the centre, and to monitor the extent to which the centre achieves its scientific objectives. The scientific

deputy director also advises some of the post-doctoral researchers at ELSE. He also oversees the scientific conference and workshop programme of the centre.

The current scientific deputy director of ELSE is David Shanks, a professor of psychology at UCL. He has been in this position since 2001. Between 1995 and 2001 ELSE had a “scientific director”. This position was initially held by Ken Binmore, and later by Henry Plotkin, a professor of evolutionary psychology at UCL.

The *executive committee* of ELSE consists of the director, the two deputy directors, and three further senior researchers at ELSE. The executive committee meets two or three times per academic term to oversee ELSE’s research and finances, and to take all major decisions concerning the centre.

Beyond the individuals listed so far the following are currently members of the executive: Celia Heyes, a professor of psychology at UCL, Steffen Huck, a reader in economics at UCL, and Rob Seymour, a professor of mathematics at UCL. Celia Heyes is the director of the two experimental laboratories of ELSE. She oversees work in these laboratories, and prioritises experiments.

ELSE’s research is organised in research divisions. Each research division has its own head. The *heads of the research divisions* are appointed by the ELSE executive. The research division heads provide research leadership in the area covered by their research division. They also monitor the extent to which ELSE achieves its research objectives in this area. The research division heads report annually to the ELSE executive at the time of the preparation of ELSE’s annual report to the ESRC.

The members of ELSE’s *advisory board* are listed in Annex D. The advisory board meets twice per year and receives reports from the director and the administrative deputy director about the centre’s progress. The advisory board advises the director and the administrative deputy director about issues related to ELSE. In particular, they advise about possible contacts with non-academic users of ELSE’s research. The advisory board also comments once per year on a draft version of ELSE’s annual report to the ESRC.

ELSE’s *administrative staff* consists of the ELSE administrator and an administrative assistant. The administrator manages ELSE’s finances in collaboration with the director and the administrative deputy director. The administrator also co-ordinates ELSE’s reporting to the ESRC. The administrative assistant supports the administrator and the directors in their tasks. She also administers ELSE’s visitors programme, and arranges ELSE’s events, such as conferences and workshops.

From 1995 until 2002, Sandra Semple was the administrator of ELSE. In 2002 Sandra Semple took early retirement. Rosie Mortimer replaced her. The administrative assistant is Sonia Malkani.

4.2 Management Procedures

In this subsection we list some key management functions, and indicate how they are performed and who performs them.

(a) Scientific Leadership

This is in the first place the responsibility of ELSE’s director and its scien-

tific deputy director. They seek to stimulate research so that ELSE achieves the research objectives agreed with the ESRC. Providing scientific leadership in specific areas is, in addition, the task of the heads of ELSE's research divisions.

How do the director, scientific deputy director and the heads of the research divisions provide research leadership? Firstly, of course, like other members of the ELSE executive, they undertake their own research.

But the research of ELSE is not exclusively, nor even predominantly, the achievement of the ELSE executive. It is the work of the ELSE Research Fellows. ELSE has currently 24 research fellows. These research fellows come from the fields of economics, psychology, mathematics, and anthropology. The majority of the research fellows are full time members of the teaching faculties of their universities, typically UCL.

The philosophy behind our approach to research leadership is that no academic researcher can be directed to undertake good research. We do not instruct individuals regarding which research projects they need to undertake. Our strategy is to hire researchers whose research interests are naturally in our fields of interest, and to enable them to conduct the best research of which they are capable.

We support these researchers' work in a variety of ways. Depending on their needs, we either reduce their teaching load by buying out some of it, or we hire research assistants for them, or we provide other forms of research support, such as travel support and computer equipment purchases.

Some of the research fellows are post-doctoral researchers who have been specifically hired by ELSE. Currently, ELSE has seven such post-doctoral research fellows.¹

How do we ensure that the research fellows undertake research which furthers ELSE's research objectives? The ELSE research agenda is regularly explained to the research fellows and discussed with them. ELSE research fellows are asked each year to indicate what research they have done and how the research contributes to achieving the research objectives. If a research fellow's work does not contribute to the ELSE objectives then ELSE funding is discontinued.

To motivate ELSE research fellows, and to inspire their creativity, the director and the scientific deputy director undertake the following duties:

Conducting research that provides inspiration for others in the centre.

The senior researchers at ELSE, including the director and the scientific deputy director, seek to undertake research that is at the heart of ELSE's research agenda. Binmore, for example, has undertaken active research in the evolutionary research division and the mechanism design research division of ELSE. Börgers conducts research in the learning division and the mechanism design division. Shanks carries out work in the learning and behavioural economics divisions.

Inviting centre researchers to collaborate.

¹ Two of these post-doctoral research fellows are funded by ESRC fellowships, and one is funded by the Leverhulme Trust. ELSE acts as host to these researchers.

The senior researchers at ELSE collaborate actively with other ELSE researchers. Binmore has repeatedly worked together with Vaughan and Swierzbinski. Börgers undertakes joint research with Huck, for example. Shanks works with Newell and Tunney. Plotkin has worked with Dunbar. Heyes has worked with Ray.

Commenting on colleagues' research.

The ELSE director and the scientific director participate in all seminars related to ELSE's research, and comment on the research presented there. They also meet regularly with individual colleagues to update their knowledge of and to provide advice on their research. This applies in particular to the post-doctoral researchers involved with ELSE. The director meets with each post-doctoral researcher at least once per term to review research progress.

Annually reporting the progress towards achievement of the centre's objectives.

Preparation of the annual report of ELSE to the ESRC offers the ELSE director and scientific deputy director an opportunity to monitor the extent to which ELSE makes progress in achieving its research objectives.

Participation in hiring decisions.

The ELSE director and the scientific deputy director participate in all sub-committees that hire research staff for ELSE. They insist that research staff are employed whose research contributes significantly to the ELSE research agenda, and whose research is not yet covered by other members of ELSE's research staff.

(b) Seeking and Maintaining Contacts with Non-Academic Users:

Contacts with non-academic users help us to shape our research so that it addresses problems which matter in the real world, and they help us to disseminate the results of our research to those who are most likely to use them beneficially.

Establishing and maintaining contacts with non-academic users are primarily the responsibility of the director and the administrative deputy director. They undertake the following activities. They are supported in this task by the advisory committee.

Establishing new contacts.

To achieve this the director and administrative deputy director seek personal contacts with many members of government and business whose work might benefit from ELSE's research. Many of these contacts are informal, but it has turned out to be useful occasionally to organise conferences on issues that are relevant to particular user communities. Our experience has been that such events are successful only if they are focused on very specific issues, and if practical relevance of all presentations is ensured throughout.

In the past few years, following the spectacular auctions of licenses for third generation mobile telephony, the establishment of new contacts has also been facilitated by the many approaches which ELSE has received. Often, if we only responded to telephone calls and e-mails, we have had a more than sufficient set of contacts with interested non-academic parties. We believe that this is a temporary effect due to the mobile telephony auctions, and that in the next few years we

shall have to move again into a more active mode to establish contacts. The help of ELSE's advisory board will then become again more crucial.

Acquiring advisory contracts.

The main focus of our contacts with non-academic users are advisory contracts. Typically, we respond to invitations to tender, and we receive these invitations through the contacts which the director or administrative deputy director have initiated. The director and the administrative deputy director regularly prepare bids. Sometimes they co-operate with other members of ELSE, and sometimes they leave the preparation of bids to other members of ELSE.

Managing advisory contracts.

In the first few years of ELSE choosing the appropriate framework for the management of advisory contracts was a major task for the management of ELSE. In due course a separate company, called ELSECo, was set up, which acted as the contracting party for our non-academic contacts. A full time managing director of ELSECo was employed. Tony Curzon Price filled this position. The main purpose of the establishment of ELSECo was the development of an ELSE reputation in the area, and the creation of an entity that could carry the liability for any advisory contracts.

In 2001, when the ELSE management changed, it was decided to somewhat scale down ELSE's advisory work, and to re-focus ELSE on its fundamental research purpose. At the time, advisory work was taking up a very significant proportion of the time of senior ELSE management. One implication of the reduction in ELSE's advisory work was that it no longer seemed desirable

to undertake work at a level which would fund the infrastructure required by ELSECo. ELSECo is now in the process of being wound up.

Feeding back into research.

It is of crucial importance to ELSE that the experience which ELSE acquires in its advisory work feeds back into our research work. To achieve this, the ELSE director and administrative director seek to identify research needs arising from ELSE's advisory work. They then steer ELSE research into the relevant directions, applying the methods that were earlier described in this report.

(c) Exercising Financial Control

This task is jointly performed by the director, the administrative executive director, and the administrator. The most important activities that are involved in this task are as follows.

Deciding about proposed expenditures.

For small, research related expenditures each research fellow of ELSE has his or her own research budget. Research fellows can use this budget without requiring approval from the ELSE management provided that it is clear that the expenditures are research related.

Larger expenditures require either the approval of the administrative deputy director, or, if they are very significant, of the ELSE executive committee.

Financial reporting.

The ELSE administrator prepares regular financial reports for the ELSE executive and for the ESRC. The purpose of these reports is to monitor ELSE's

expenditure levels. They help the ELSE management and the ESRC to monitor whether ELSE stays within its budget, and whether it spends its money on the right priorities. The ELSE executive receives a financial report at each of its meetings. The ESRC receives a financial report with ELSE's annual report.

A major difficulty in this area is that the financial accounting system of the college does not provide information in a form in which the ELSE executive could use it for monitoring and decision making. We have therefore developed our own internal accounting system. This, however, creates a regular need for synchronising the college accounts and our own accounts.

(d) Raising Third Party Funding

The director, the administrative deputy director and the administrator regularly monitor third party funding opportunities. They then either prepare grant applications themselves, or they suggest to other colleagues in ELSE that they should apply for new grants.

(e) Managing ELSE Personnel

It is crucial to ELSE's success that we attract and retain good research and support staff.

Hiring decisions at all levels involve the director, the administrative director and the scientific director. The procedures that we adopt for hiring new staff follow meticulously the corresponding rules of University College London.

All ELSE staff are annually reviewed. The reviews for post-doctoral researchers are carried out either by the director or by the scientific deputy di-

rector. The computer and laboratory staff are reviewed by the director of ELSE's experimental laboratories, and by their respective line managers. The administrative staff are reviewed by the administrative deputy director of ELSE, and by their respective line managers.

All ELSE staff are encouraged to participate at least once per year in training activities. Training activities are selected according to job requirements and staffs' career goals. Adequate training raises job performance and job satisfaction. It also raises our staff's job market prospects, which is crucial given that ELSE is funded out of time-limited grants.

Post-doctoral researchers are given the largest possible freedom to develop their research and their publications. We try to minimize the extent to which post-doctoral researchers are burdened with administrative task.

Post-doctoral researchers are typically hired for a limited period of two years only while administrative and computer staff are typically hired without such a time limit. It is therefore important to prepare post-doctoral researchers for the academic job market as they leave ELSE. This is primarily achieved through good research. We also offer help with the preparation of job-market papers and talks, as well as with interview preparation. Where placement programs exist in the academic departments involved, the post-doctoral researchers are integrated into these programs.

Post-doctoral researchers who leave ELSE have found good positions. Examples are Geoff Miller's current position as assistant professor of psychology at the University of New Mexico, Thomas Tröger's position as assistant

professor of economics at the University of California at Santa Barbara, and Peter Sozou's position at UCL's School of Public Policy. The destinations of all researchers who have left ELSE are listed in Annex C.1.

Administrative staff and computer staff must, of course, also keep an eye on their future employment, as ELSE's grant is only of limited duration. We encourage our staff to think early and regularly about their future career, and to take as early as possible the necessary steps to develop good career prospects. For example, we currently support one member of our computer staff (Onouha) to undertake advanced training. For another member of our staff we are seeking together with the economics department to find ways of developing and extending his experience at managing people.

4.3 Role of the Centre Within the University

The centre spans several departments within University College London: psychology, economics, and mathematics. The centre also involves researchers from two other universities: London Business School, and the Saïd Business School at Oxford University. However, the most important interactions with university institutions occur at UCL.

The most important management decisions concerning ELSE are made in consultation with the Provost of University College London. The recent change in directorship of ELSE was, for example, implemented only after careful consultation of the Provost.

Day-to-day interactions occur typically with the department chairmen of the economics and of the psychology de-

partment. Both departments are highly ranked (5*) in the research assessment exercise, and both departments know of the importance of ELSE for the maintenance of their research ranking. ELSE facilitates a large proportion of the research which earns these departments their 5* ranking.

In return, these departments have made generous space allocations available to ELSE. The concerned department chairmen have also ensured that ELSE researchers' teaching and administrative obligations leave enough time for their research. Relations with the psychology and the economics department have been entirely amicable and constructive.

ELSE is also integrated in other ways into the research life of several departments. For example, ELSE sponsors the weekly economic theory workshop in the economics department of UCL. ELSE also supports financially the fortnightly seminar series on evolutionary psychology at the University of Liverpool. This series has been running for five years now and attracts audiences of 40-50 from a range of departments in the North West of the United Kingdom.

4.4 Relations of the Centre With the ESRC and Other Parties

The director of ELSE represents ELSE towards the ESRC. He comments at meetings of ESRC centre and programme directors on major ESRC policy decisions. The director can bring to these meetings the specific perspective of a centre that is, firstly, highly interdisciplinary, and that has secondly, very highly visible policy impact. ELSE has argued within the ESRC in favour of a realistic approach to interdisciplinary research. It has also de-

fended the importance of fundamental research.

ELSE can put these arguments within the ESRC from a position of relative strength. ELSE's policy involvement has made the centre very important to the ESRC. The ESRC has repeatedly used ELSE as a leading example of a successful research centre. This is documented by the citations from the ESRC's chief executive which were included into Section 1.1.

5. ESRC and Non-ESRC Funding

ELSE has received from the ESRC two five-year tranches of core funding; the first tranche from 1/10/1995 to 30/9/2000, and the second continuing from 1/10/2000 to 30/9/2005. In addition to this core funding, ELSE is supported by the contributions that it receives from the host institution, University College London, and from the fund-raising activities of the researchers at ELSE.

Table 1 is a statement of these resources, for the academic years from the inception of ELSE, to the end of the current academic year, 2001/2002.

Table 1 indicates a success: We have raised more money in co-funding than we have received in core centre funding. The amounts of co-funding have grown steadily over the first few years of ELSE's existence. After this initial growth period we have consistently maintained co-funding levels of around £500,000 per year, with a particularly large amount of co-funding in 2000/2001 due to our successful bid to the Joint Infrastructure Research Initiative (JIF) (see below).

A breakdown of the sources of this co-funding is found in Table 2. Table 2 should be read in association with Table 2 in Annex C where the projects that provided co-funding are listed in detail.

Some highlights deserve special mentioning here. The largest single grant that we have obtained is the grant from the Joint Infrastructure Initiative. This grant alone was much larger than, for example, one whole year of ESRC core funding for ELSE. This grant was

raised under the leadership of David Ulph. It was used to install a new experimental laboratory. This laboratory is also used by the "Centre for Microdata Methods and Practice" for user courses on econometric methods. The grant also funds the current IT staff who service the laboratory.

Very substantial amounts of money were raised by former executive director David Ulph from the European Community. Ulph raised a grant on "Growth, Inequality and Training" from the European Community which involved several European Universities, but for which Ulph was the coordinator. The total amount of this grant was 720,000 Euros, of which £135,000 fell to us. Other projects in which Ulph was involved include a very large TSER grant on Research Joint Ventures.

The psychologists in our group also obtained very substantial research grants. These grants were given to us by research councils other than the ESRC, and funded research on issues such as imitation, probability judgement and covariation learning. Executive members Cecelia Heyes and David Shanks were outstandingly successful in this area. As a final highlight of co-funding Ken Binmore's Leverhulme Research Professorship needs to be mentioned.

A remarkable feature of Table 2 in Annex C is that the advisory work that we have undertaken has actually raised relatively little money. The income obtained from these activities is certainly in no proportion to the resources absorbed by these activities.

None of the co-funding displayed in Table 2 would have been possible without the ESRC's core grant, however. The core grant has made it possi-

ble for us to initiate the research that later lead to large grants from other funding institutions. The core-grant has also enabled us to develop user relations without immediate commercial pressure. The Table thus indicates how the ESRC's investment in ELSE has borne fruit.

Table 1: ELSE Funding Sources, 1995/96 - 2001/2002
(by Academic Year, October 1-September 30)

£'000

Source	1995/ 1996	1996/ 1997	1997/ 1998	1998/ 1999	1999/ 2000	2000/ 2001	2001/ 2002	Total	Type
ESRC	413	399	422	453	464	465	471	3087	Core
UCL	250	248	212	260	236	269	280	1755	Host
Co-Funding	191	204	363	636	497	959	576	3426	Co-funding
Total	854	851	997	1349	1197	1693	1327	8268	

Sources: ELSE Special Report, 1995/98; ELSE Annual Report, 2001; Appendix C, this Report. ESRC non-core funding has been included in the category "Co-funding" in the above table, which accounts for discrepancies in totals compared with tables from the original reports.

Table 2: Sources of Co -Funding Income, 1995/96 – 2001/2002
(By Academic Year, October 1-September 30)

£'000

Source	1995/ 1996	1996/ 1997	1997/ 1998	1998/ 1999	1999/ 2000	2000/ 2001	2001/ 2002	Total
(a) UK Re- search Councils	63	105	49	180	182	313	202	1094
(b) Other UK Re- search Bod- ies	65	65	65	90	89	235	159	768
(c) UK Government and Agen- cies	14	0	47	53	5	126	155	400
(d) Industry and Com- merce	0	0	55	149	74	142	0	420
(e) Euro- pean Com- munity	49	34	140	161	147	74	29	634
(f) Non-UK Research Bodies	0	0	7	3	0	31	31	72
(g) Non-UK Government Agencies	0	0	0	0	0	38	0	38
Total	191	204	363	636	497	959	576	3426

Sources: *ELSE Special Report, 1995/98; ELSE Annual Report, 2001; Appendix C, this Report.* ESRC non-core funding has been included in the category "UK Research Councils" in the above table, which accounts for discrepancies in totals compared with tables from earlier annual reports .

6. The Wider Picture

Some of ELSE's contributions have had significant national and international influence. ELSE's research has also been developed in a dialogue with researchers and policy-makers in Britain and around the world. In this section we first deal with the way in which ELSE's research on learning, evolution, and behaviour fits into the international picture. Then we discuss ELSE's contribution to auction design.

6.1 Evolution, Learning and Behaviour in Games

The bringing together of evolutionary insights, learning theory, and game theory has not just been ELSE's project for the last seven years, but at the same time researchers around the world have worked on research that points in the same direction. ELSE's interdisciplinary nature has meant that it was well placed to contribute to this worldwide research effort. Few other research centres in the world have a similar interdisciplinary mixture of expertise. Our contribution has been timely, and, in some areas, researchers at ELSE have taken a worldwide lead in research in this area.

The area in which ELSE's impact on the international research community has been strongest is perhaps the theory of evolutionary equilibrium selection in games. This field is of great interest to economists. It has been one of the most active fields of research in game theory in the past ten years.

One reason why ELSE's contribution to this field had such a large impact is that one of ELSE's founders, Ken Binmore, was instrumental in the crea-

tion of this field in the 1980s. Binmore's critique of the then predominant research programme of "refining Nash equilibrium" was a catalyst for the rise of evolutionary methods for the selection among Nash equilibria. Binmore argued that to discriminate between different outcomes of games, all of which are compatible with players' rationality, one needs to model first how players become rational. The most plausible answer to this question was either evolutionary adjustment, or trial and error learning. Moreover, it appeared that formally evolutionary adjustment and trial and error learning would be closely related.

This approach to equilibrium selection became operational through pioneering work by Kandori, Mailath and Rob, all at the time at the University of Pennsylvania, and by Young, then at the University of Maryland. These researchers showed for a particular example how evolutionary dynamics did indeed lead to clear-cut predictions about which equilibrium would be played, provided that some random term was introduced into the dynamic model.

Researchers at ELSE, under the direction of Binmore, have taken up the research lead provided by Kandori, Mailath, Rob and Young enthusiastically, and probably the research done at ELSE to extend the evolutionary research programme was the leading work in this area. This applies in particular to the work of Binmore, Samuelson and Vaughan, who have shown how different time frames were crucial to the earlier results, and who have extended the earlier analysis to much larger classes of games.

Other researchers, whose work on evolutionary game theory has also been

path-breaking, such as the work of Hofbauer from Vienna, Schlag from Florence, and Weibull from Stockholm, have been less focused on equilibrium selection, and more concerned with other features of evolutionary dynamics. These researchers' work and the work undertaken at ELSE thus nicely complement each other.

Although it seems plausible that evolutionary models can be viewed as simple reduced form models of trial and error learning, the precise connection is not obvious. The work by Börgers with Sarin on reinforcement learning and evolutionary dynamics has helped to draw attention to the fact that evolutionary models, if applied to social science contexts, need an interpretation, and that this interpretation can be expressed in formal theorems.

Börgers and Sarin's work has also helped to focus researchers worldwide on the formal properties of models of reinforcement learning in general. Interest in these models has been high because prominent researchers in the US, in particular Roth from Harvard and Erev from Columbia (New York), had argued that reinforcement learning models were suitable to explaining a large variety of experimental evidence. Börgers and Sarin's work was timely because it responded by studying reinforcement learning analytically.

Within the United Kingdom ELSE has been a catalyst for research on learning, evolution, and games. Researchers with an interest in this area have visited ELSE frequently and have presented their work here. Other researchers have completed their doctoral theses at ELSE and have since taken up teaching and research positions within the UK. Our leading role in this area is also emphasized by the fact that Tilman Börgers and Murali Agastya or-

ganized for four years together with Martin Cripps from Warwick the "ESRC research seminars in game theory" which were jointly funded from a direct grant from the ESRC, and from ELSE's grant.

6.2 Evolutionary Thinking as a "Universal Acid"

Daniel Dennett has famously described evolutionary thinking as a "universal acid" that infiltrates not just all of biology, but many other sciences as well. The 1990s have seen a revival of evolutionary thinking about human behaviour. This is witnessed by the highly popular work of Daniel Dennett, Richard Dawkins, Steven Pinker, and many others.

ELSE researchers have contributed significantly to this research and its popularisation. Dunbar's ideas on the origins of language (the "gossip theory") have been widely taken up elsewhere in the humanities and social sciences. His work on the cognitive limits of social networks (the "brain size/group size theory") has also attracted considerable attention not just among academics but beyond, even in the business world. Dunbar's most recent book (with Barrett and Lycett) is a synthesis of all recent work on evolutionary psychology, and seeks to provide a foundation on which future work can be built.

Geoffrey Miller's book "The Mating Mind" brought the role of sexual selection in evolution to the forefront of the international debate. Miller argued that many human traits, including human intelligence, could be viewed as displays in courting behaviour, and thus as adaptations created by sexual selection. Miller's work was translated into

many languages, and attracted large interest in many countries.

Plotkin's book *Evolution in Mind* was reviewed by the philosopher Jerry Fodor as "the best statement you can find in print of a very important contemporary view of mental structure and process".

Ken Binmore explored the implications of evolutionary thinking for political philosophy in a pair of books on Game Theory and the Social Contract. Binmore argued that norms of "good" behaviour served the purpose of helping society to coordinate on selected Nash equilibria of the large "game of life". At the same time, Binmore suggested that norms of "good behaviour" which did not correspond to equilibria could not be sustained.

Binmore's work in this field presents an original and new angle on the old issue of evolution and moral or altruistic behaviour about which much has been written in the past decade. Binmore's emphasis on moral norms as equilibrium selection devices distinguishes his work from that of others who had primarily emphasized the fact that equilibria might involve altruistic behaviour.

6.3 Experiments and Rationality

The 1990s have seen a revival of experimental psychologists' interest in learning, and ELSE has played a leading role in this development. Researchers under the leadership of David Shanks have revisited many of the issues (such as the effects on learning of different types of feedback, the origin of choice anomalies in repeated decision tasks) that were first raised by psychological research on learning in the 1950s and 1960s. Interest in these

issues has been revived for several reasons, including the following: First, psychologists have made great strides in developing computational models of behaviour in specific learning problems and have become much more focused on characterizing what an optimal decision maker would do (Shanks has been a key figure in this area with his work on causal inference). Secondly, economists became more interested in the link between learning and rationality than they had been in the 1950s and 1960s and this has influenced psychologists' thinking.

Our research in this area has attracted international attention. Our centre is to our knowledge one of very few centres around the world where psychologists and economists work side by side on these issues.

Our centre is also well placed for the extraordinary expansion of experimental research among economists. Our experimental laboratory, financed with a grant from the Joint Infrastructure Fund (JIF), is a very high quality research facility. With Steffen Huck, one of Europe's best experimental economists, joining ELSE we hope to play a prominent role in the worldwide research efforts in experimental economics.

There are other well-known centres for experimental research in economics in the United Kingdom, with York and East Anglia perhaps being the most prominent ones. These centres differ from ours in that their focus has traditionally been on choice under risk, whereas our focus is on learning and on research about auction mechanisms and Industrial Organisation. But as our centre and the centres in York and East Anglia, and also in the rapidly expanding University of Nottingham develop we shall watch out for possible over-

laps and opportunities for collaboration.

6.4 Behavioural Economics

During the seven years in which ELSE has now been in operation there have been important developments in our research areas which, although they were not initiated by us, did require a response from us. The most important such area is that of “Behavioural Economics”. This area, which has rapidly gained importance in the last few years, has set itself the task to record systematic deviations from economic rationality that are observed in experiments and in practice, and to incorporate these deviations into economic theory. If, for example, individuals systematically make dynamic decisions using very short time horizons, then, behavioural economists argue, the economic theory of savings formation should reflect this. Behavioural economists have recently applied these ideas to many areas of applied economics.

The agenda of behavioural economics is a mirror image of the research area of ELSE. Researchers at ELSE have typically tried to identify those areas in which the traditional view of economic rationality does predict well. ELSE researchers have argued that the part of economic life in which traditional economic rationality is adequate is quite large.

However, there is no necessary conflict between behavioural economics and ELSE’s research. It seems that the two approaches differ in emphasis rather than in substantive claims. Moreover, as behavioural economics is very focused on the interaction of psychology and economics, it seemed that ELSE as an interdisciplinary centre covering

among others these two disciplines should respond to and be involved in the debates about behavioural economics. Since 2001 we therefore have a research division on behavioural economics where we work on a limited and focused research programme in this area. The formation of this research division exemplifies how ELSE responds to research developments in the international research community.

6.5 Auctions in Theory and Practice

Our involvement in spectrum auctions has been very prominent in the United Kingdom and Europe. We have followed in this area the lead of the United States. In the 1990s the Federal Communications Commission of the United States began to conduct auctions in which licenses to use the radio spectrum were sold to mobile telephone companies. This was a very significant policy development because it potentially improved spectrum allocations and raised significant revenue for the government budget with relatively little distortion. This development was also very interesting from the point of view of an academic economist because it is by far the most prominent policy application of game theory. Indeed, several of the best-known American game theorists were the lead advisors to the FCC and to bidders in the FCC’s auctions.

After the US auctions it was clear that the European governments would follow in some way. These governments would have to bring in expertise in auction design, and game theorists based in Europe were perhaps better placed to offer such advice than US game theorists were. ELSE noticed this opportunity and became involved from very early on. This led to our work in

the UK, which is described elsewhere in this report.

The United Kingdom's third generation spectrum auction was widely observed throughout Europe and the rest of the world. Many European governments tried to imitate the UK government in one way or the other. Thus, the advice which we offered to the UK government has had echoes elsewhere. In a number of countries members of ELSE were indeed hired as advisors. Examples are Denmark, Greece, the Netherlands, Latvia, and Hong Kong.

Overall, it thus seems fair to say that ELSE's work on spectrum auctions was instrumental in transferring a policy innovation from the United States to the United Kingdom, and to many other countries in Europe and other continents.

ELSE will continue to work on these issues. We expect our current projects, for example our work on secondary trading of licenses, or our work on auctions in environmental policy, to have significant international policy implications. At this stage there is no research centre in Europe that can match our experience and expertise in this area.

7. Future Plans

In the next three years ELSE will conclude its current research programme as agreed with the ESRC. At the same time we shall position ourselves for continued activity beyond the current funding horizon. We begin this section by explaining our plans for completing the current research programme. Then we describe how we plan to position ourselves for renewed activity beyond 2005.

7.1 Completing Our Current Research Programme

Among the three research divisions that are concerned with fundamental research, the divisions on Evolutionary Approaches and on Learning Approaches have reached relatively mature stage. In the Evolutionary Division Ken Binmore's plan to write a popular version of his books on political philosophy will be a major task. This new book will contribute very significantly to the dissemination of our results in this area.

In the learning division we shall primarily work experimentally. We shall continue our systematic collection of experimental evidence of learning. We shall also sharpen our methods for analysing such data. We plan to develop advanced non-parametric methods for the analysis of learning data. We shall then use these methods to analyse which types of prior and feedback information have the largest effect on the speed of agents' learning. We shall develop this research partly in collaboration with researchers at the Centre for Microdata Methods and Practice (Cemmap), a joint venture of UCL and the Institute for Fiscal Studies.

Shanks, together with Newell, Lagrado, and Tunney is now writing a book which aims to integrate psychological and economic research on learning theory with that on decision making and which will attempt to defend rationality against a number of strong recent attacks such as that from Gigerenzer.

Our division on Behavioural Economics is still relatively new. Our plan is to conduct a compact and focused research programme that can be completed within the next three years. This includes in particular research on incentive contracts when agents are inequity averse, research on imperfect recall, and research on boundedly rational decision algorithms.

Turning next to the research divisions that are concerned with economic applications, we shall continue advisory work in the area of mechanism design, although to a lesser extent than in the past. Spectrum license auctions are continuing, primarily in Eastern Europe. We will continue to be involved in them. We anticipate some further involvement in advice on auctions in the gas sector, and some further work on organised markets for a variety of license type instruments.

We shall also seek to strengthen our academic competency in this area. We have several ongoing research projects, which were inspired by the recent spectrum auctions in the United States and Europe. The US experience, for example, suggests that collusion in open ascending auctions is an important topic. The European experience indicates that auctions in which bidders care about their relative position in comparison to other bidders play an important role. We shall seek to explore these issues theoretically. Another area in which there exists an ob-

vious need for further research is the auctions where bidders have multi-unit demand.

Our academic work on auctions will not only be theoretical but also experimental and empirical. We have already undertaken a detailed analysis of the experience provided by the recent European spectrum auctions. We plan to extend our work to other data sets, possibly the spectrum auctions in the US, or possibly the gas entry capacity auctions in the UK.

At an experimental level we plan to build up significant experimental data sets on a variety of auction and market formats. This will include standard formats, but also formats such as clock auctions which have been less carefully investigated in experiments, and with which less practical experience is available.

In the area of automated trading and negotiations perhaps our most promising project at the moment is one in which we plan to combine theoretical methods, and experimental as well as field data to investigate which institutions inspire the trust required for electronic transactions.

In Industrial Organisation we shall focus on empirical research regarding the determinants of innovation, and we shall develop an experimental research programme on mergers.

At a personnel level we anticipate that UCL will hire during the next three years two further senior professors of economic theory, who will both contribute to the research programme and to the management of ELSE. We expect that these researchers will also help to position ELSE for the future beyond 2005.

We shall also hire one further generation of post-docs. The typical period for which we hire post-doctoral researchers is two years. The current generation of post-doctoral researchers will leave their positions in 2003. This means that there is one further opportunity to hire young researchers. In the 2003 hiring round we shall seek to appoint researchers whose research is closely focused on ELSE's remaining research programme, as indicated above. A tighter focus than in the past is needed because at this stage we do not want to start entirely new research projects.

As far as ELSE's administrative structure is concerned we hope to maintain the current composition of the executive until the end of the funding period. All members of the executive are planning to remain in their positions until 2005. We also aim to keep both the administrative staff and the computer support staff in their positions. We offer career advice and training possibilities to all our staff, so that, depending on the final decisions about the future of ELSE, the administrative and computer staff are well placed either to continue working in ELSE, or to seek new employers.

7.2 ELSE Research Beyond 2005

We plan to continue to operate as a major research centre beyond our current ESRC funding period. The research agenda that we shall pursue after 2005 will emphasize those areas in which ELSE has a comparative advantage. From 2005 onwards we shall seek to provide ELSE with a stronger focus, thus addressing the issue of excessive diversification that we have raised earlier.

The details of our research agenda beyond 2005 will depend, among other factors, on the senior professorial appointments that UCL will make to replace Ken Binmore and David Ulph. However, at this stage it appears that there are two major areas of research where ELSE has a strong comparative advantage. The first such area is that of evolution, rationality and behaviour. We have a comparative advantage in this area because we are an interdisciplinary team of researchers who are used to interacting with each other, and who have undertaken leading research in evolutionary psychology and game theory.

How do we want to develop our research in this area? Firstly, we believe that there are further theoretical problems in this area that deserve our attention. It has become a more widespread belief that humans use certain simple algorithms that are evolutionarily adapted to specific environments that were important in our evolutionary history. It is an important theoretical task to say precisely what is meant in this statement by a “simple algorithm”, and to develop a formal theory that allows a closer study of the trade-offs between simplicity and adaptation. Ingredients of such a theory exist, but it has been developed only for a very small set of contexts yet. We are interested in extending this theory.

Secondly, we believe that areas such as evolutionary psychology and evolutionary game theory need a stronger experimental and empirical foundation than they currently have. Work in these areas is often still of highly speculative nature. We hope to contribute to the collection of empirical and experimental evidence. This research will make good use of the experimental facilities and computing facilities that we ac-

quired in our successful bid to the “Joint Infrastructure Fund”.

Thirdly, we anticipate that, over the time horizon that we are considering here, work in this area can be taken closer to users. For example, if evolutionary theory and experimental evidence suggest that humans are ill adapted to environments with idiosyncratic risk that follows no pattern over time, then perhaps something can be done to help fund managers to recognize such risks. If humans respond well to particular graphical clues, then perhaps interaction systems that use such clues are particularly useful. If human learning gets faster if ample of opportunity of imitation is offered, then this might provide us with hints how to promote learning among students. These are some examples of possible practical applications of evolutionary psychology and learning theory that we might explore.

The second research area in which a sustained research effort seems required is that of auction and market design. We believe that we have only seen the beginning of applied economic work in this area. Auctions are pervasive in government policy and the business world. They are used when the rights to live transmission of football matches are assigned, when entry capacity to the gas transmission system is allocated, and when spectrum licenses are awarded. In many cases, secondary markets with more or less well-defined market rules follow initial auctions. Trading rules govern the trading at financial and commodity changes. In all these areas expertise in the design of auction and market rules will be required.

Game theory and auction theory have much to offer to the designers of auctions and market rules. However, more

work is needed to consolidate and expand our knowledge. The need for work concerns three areas:

- *Theoretical work:* A better understanding of many aspects of the theory of auctions and trading mechanisms is needed. Examples are the theory of auctions with budget constraints, auctions where bidders are concerned about their relative position as compared to other bidders, and auctions where bidders have multi-unit demand.
- *Experimental work:* Experiments have been a crucial tool for auction design. The purpose of experiments is not so much exactly to mimic the behaviour of real bidders, but to understand whether rules are well defined, easily understood, and whether there are obvious possibilities for bidders to exploit rules to their own advantage. Any further development in auction theory will need to be accompanied by experimental work. In conducting this work, we shall make good use of the experimental facility that we acquired in the “Joint Infrastructure Fund” bid.
- *Empirical work:* In the long run practical auction and mechanism design will be successful only if it is grounded in real world experience. Auction theorists and game theorists have only begun systematically to collect and evaluate the available evidence about bidder behaviour in auctions and market mechanisms.

ELSE has a comparative advantage in this areas not only because of its practical experience in the area of auction design, but also because some of Europe’s leading auction theorists work at ELSE, because we have a high

quality experimental laboratory with leading experimental researchers standing ready to use it, and because our group has links with economists at UCL whose wide-ranging expertise in data analysis is unrivalled.

7.3 Funding Structure Beyond 2005

We anticipate that, beyond the current funding period, ELSE’s research will increasingly rely on funding sources other than ESRC centre funding. We see such funding sources primarily in other research funding organisations in the UK, such as the Leverhulme Trust, in the European Community, and in governmental and private organisations in the UK and abroad which commission research. We shall also seek renewed ESRC research centre funding. On the other hand, it is *not* our plan to make direct consultancy contracts a primary source of funding of our activity.

The guiding idea behind these plans is that we continue to undertake research that combines academic excellence with user relevance. We will seek funding sources which allow researchers at ELSE to undertake long-run research at high international standards, and which, although user relevant, is not driven by the requirements and strict deadlines of consultancy work. ELSE researchers will undertake limited amounts of advisory work so as to stay in touch with real world problems, but we shall exercise careful discretion in choosing the projects in which we would like to become involved.

Our ability to raise co-funding from sources other than consultancy income is proven by the track record documented in Section 5 of this report, and also in Annex C to this report. We see further opportunities in this area. ELSE

is, for example, well-placed to participate in networks of excellence under the European Community's Framework 6 programme. As indicated elsewhere in this report, we have already been part of several expressions of interest under this programme. Our reputation in the area of auctions and mechanisms design will lead to further research commissioning, in particular if we link up with the

Finally, there is a strong case for further centre funding from the ESRC. Our research on boundedly rational decision making and on the evolutionary foundations of human behaviour is a long-term research effort. Research in these areas often generates strong public interest. But taking this research to applications and users is difficult. As explained above, we plan to make first steps into this direction. But these steps are speculative, and cannot replace government support for our work.

Similarly, government support will also be important to our work on auctions and on market rules. Some projects in this area, for example work on auctions with multi-unit demand, progress by their nature slowly. Because we cannot promise immediate benefits, such projects are unlikely to attract funds from individual firms or government agencies. However, in the long run they will undoubtedly bear fruit. They therefore commend themselves for ESRC support.