

Public choice and the development of modern laboratory experimental methods in economics and political science

Charles R. Plott

Published online: 7 September 2014
© Springer Science+Business Media New York 2014

Abstract The paper is an account of the development of laboratory experimental methods in the early 1970s as influenced by the fields of Public Choice and Social Choice. Just a few key experiments conducted during a period when no experimental markets research was taking place, provide a bridge with the subsequent, rapid, growth of experimental economics. A new focus on public goods and externalities, as opposed to private goods traditionally used in economics experiments, required new representations of the commodity space and preference inducement methods. The importance of voting and collective decision making processes dictated the testing of equilibrium concepts from political science and cooperative game theory as opposed to the competitive equilibrium and Nash equilibria found in economics. The existence of many theories from multiple disciplines required new experimental designs and experimental tests. The Public Choice and Social Choice emphasis on comparing the performance of different types of collective decision processes induced early experiments related to institutional design and testing.

Keywords Experiments · Early history · Public choice · Committee experiments

JEL Classification B2 · B3 · C9 · D7 · H0 · H4

1 Introduction

The introduction of Public Choice topics in the 1970s was a major transition in the use of laboratory experimental methods as applied to economics and political science. The transition can be recognized by the change in the focus of laboratory experiments from private sector phenomena (markets, oligopoly, matrix games), to

C. R. Plott (✉)
California Institute of Technology, Pasadena, CA, USA
e-mail: cplott@hss.caltech.edu

the public sector and by the substantial increase in the number of papers written and topics explored. The methods changed to encompass a different approach to experimental methods, a new set of theories, a focus on institutional detail and new environments as well as a new approach to policy.

The transition took place within a narrow window of time during the first half of the 1970s when results were produced and disseminated (actual publication of many results occurred years later due to the long publication lag). At first, it was only me, my colleagues, and my students guided by my close connection to Public Choice. It quickly expanded to include other members of the Caltech faculty because several were interested in Public Choice and to Carnegie Mellon where Public Choice research was active. After those first few years, the growth was rapid, fueled by regular meetings of the Public Choice society where results were reported, enhanced by connections with axiomatic social choice and the decades earlier work on experimental markets and given visibility by special conferences in 1977 and 1978 where fundamental experimental papers were presented. Subsequently, a renewed interest in policy, created an overlap and partnership with experimental economics.

The focus this note is on is that narrow window of time and key experiments that set the stage for the subsequent developments. Public Choice and constitutional political economy played an indirect, but very important part through the perspective that Buchanan and Tullock brought to the theory of public sector decisions. The importance of the “rules of the process” had an enormous influence on the development of laboratory experimental methods. As someone who was deeply associated with the transition from the very first, I appreciate the opportunity to report on the subtle ways in which public choice theory contributed to the basic science and my participation along the way.

2 Background

The relationship between Public Choice and the development of laboratory experimental methods reflects a natural confluence of events, perspectives, and methods. In the mid-1960s, a mathematical question posed by Jim Buchanan attracted my interest and ultimately evolved into a theory that motivated several of the key experiments. Mr. Buchanan, which is how one addressed him at the University of Virginia those days, was perplexed by the Samuelson conditions for the Pareto Optimal provision of public goods. He asked about the conditions for Pareto optimality in a world that existed of only public goods. The Samuelson conditions required the existence of a private good held by everyone. It was used to measure the individual marginal values of the public good, which were then summed. Due to the absence of a private good, the technical conditions for Pareto optimality in the “all public goods” case required generalization. In retrospect, one can see that Jim’s thoughts were exploring the demand side of the provision of public goods.

As a graduate student, I became interested in the problem and managed to solve it¹ and while working on the problem, I noticed that the conditions for Pareto

¹ Soon after I developed conditions for Pareto optimality in a world of public goods, I discovered that similar conditions had been developed years earlier by Frisch (1959).

optimality are closely related to the conditions for a particular notion of voting equilibrium under unanimity in a world of public goods. A special type of dynamics was also suggested. The equilibrium notion postulated a process of proposals and movements in the world of public goods, along directions that would pass the voting test (not fail a unanimous vote) and would stop at equilibrium when no movement was possible. The proposal and movement process, which employs a search of the actions to which participants might agree, is different from the classical Nash model in which each participant optimizes given the decision function of others. The gradient of the utility function and directional derivatives became the engines of decisions as opposed to marginal rates of substitution. Positive votes required positive increases in utility in the sense that an indifferent individual would vote “no”. Of course, an idea of an equilibration process for elections had been used by Anthony Downs² and Duncan Black had considered equilibrium for committees,³ but the precise theory I used was new.

Seeing the conditions as characterizing equilibria for one set of voting institutions (unanimity), my attention turned to the same notion of equilibrium under other voting rules. Subsequently, I published conditions for a theory of equilibrium under majority rule in a world of public goods.⁴ I also considered how proposals for changes in public goods levels might be found systematically from among the infinity of possibilities.⁵ Interestingly, the existence of the equilibrium is very fragile and the equilibrium disappears with small preference changes or if private goods are added to the environment. That fragility motivated the experiments that came later.

3 An invitation for laboratory experimental methods

The connections between public choice and experiments reflect a general, scientific methodological assumption that leads from theory to experiment. Public choice theory rests on a set of general principles, much like the laws of supply and demand, which are assumed to operate independent of time, place, individuals, and many other variables. The perspective that purposeful and possibly self-interest could drive public decisions contrasts with the view that public decisions are driven only by normative views about what is good for society. The public choice perspective, now more properly viewed as the constitutional political economy perspective, suggests that an understanding of the public sector can be achieved through a study of how individualism works within a given set of institutions, as opposed to a study of alternative philosophies of public preferences that might exist apart from the preferences of the individual. Public Choice theory is behavioral in the sense that public decisions are assumed to reflect equilibrating tendencies resulting from the

² Downs (1957).

³ Black (1958), Black and Newig (1998).

⁴ Plott (1967a). This paper also contains the results regarding unanimity that first attracted my attention to the problems.

⁵ Plott (1967b).

interactions among individuals and institutions. The theoretical and empirical challenges are to identify and understand the principles at work.

The behavioral principles of public choice follow the methodological individualism of economics and are shaped by the interaction of individual preferences and institutions to determine social choices. The relationship is summarized by a “fundamental equation” that plays a background methodological role in the development and application of experimental methods.⁶ The relation is simply:

Preferences \times institutions \times feasible set \times solutions/equilibrium \Rightarrow outcomes.

The equation summarizes a hypothesis that the principles that determine public (and private) sector decisions and outcomes are located in individual preferences over outcomes, the institutions that control their information, the actions from which individuals can choose, and the physical environment that limits feasible options. By including a concept of equilibrium or solution concepts from game theory or equilibrium concepts from economics and public choice, the outcomes of the both the private and public sectors can be predicted. Models of markets, politics and games all fit within the same framework.

Theories reflecting the structure of the fundamental equation are well suited for experimental methods. The key assumptions of such theories are based on observables and can be implemented in simple cases for the purposes of study and testing. (1) The commodity space can be any abstract set of variables. (2) The theory takes no stand on the sources or shapes of preferences or the reasoning through which preference might emerge. The theory does not take a stand on why an individual has a preference. For example, the preference for a shirt could be driven by a desire to stay warm, the fact someone admired wore something similar, the fact it might attract a member of the opposite sex or by the possibility that the buyer wants to eat the shirt. From the point of view of the theory, the structure of the preference is the important feature. The source of the preference is not important, except possibly as a tool to facilitate a more accurate specification of the preference structure and shape. Thus, preferences can be induced using money or any other reward medium that people like and can have the structure of private goods, private goods with externalities or public goods.⁷ (3) The institutions can be markets, voting, and negotiation or can be more bureaucratic or administrative processes. (4) Feasibility can be directly controlled. In essence, key parameters can be held constant while institutions are changed, thereby facilitating a deep understanding of solutions and equilibrium and related impacts of institutions, the substance of public

⁶ While elements of the “fundamental equation” are evident in early writings of Public Choice, its importance as a foundation element in the development of experimental methods was only becoming recognized as laboratory experimental methods developed. See, Plott (1979). Several papers related to the development of this period are reprinted in Plott (2001).

⁷ The demonstration by Grether and Plott (1979) that preference theory could be rejected by “preference reversal” experiments performed in psychology expanded the study to include a variety of preference forms together with the possibility that preferences might be endogenous. The Grether and Plott study was an important step in expanding the study because it clearly demonstrated that preference theory as found in economics is a rejectable theory, as opposed to tautological and thus, placed the body of theory on solid scientific footing.

choice and constitutional political economy. Because the framework applies to both the public sector and the private sector, the fundamental equation brings a generality to experimental methods that did not exist before. For example, an experiment can include private markets but it also can include economic environments where private markets cannot operate.

The generality of theories as captured by the fundamental equation forms the rationale and the relevance of laboratory experimental methods. General theories, by definition, apply to simple and special cases as well as to complex and common cases. Thus, theory applies with equal force to cases that evolve naturally from historical events and cases that were created specifically for laboratory testing. The simple cases that can be created in the laboratory can thus be used to explore the reliability of the theory and make needed comparisons among competing theories. Of course, it does not follow that the results from laboratory conditions can be applied directly to complex, naturally occurring environments in which parameters are unknown and institutions are possibly different from those induced in the laboratory. The transfer of laboratory results to field environments is delicate in the case of public choice, just as it is delicate in the natural sciences.

4 Foundation experiments: identifying principles

Public choice theory suggests relationships among a broad spectrum of institutions that can be explored and refined through experimental methods. This process of discovery often begins with specific experimental questions and asks if the data produced through experiments is consistent with theory, given a best case setting for the theory. If the theory has empirical content given its best shot, a process of extension and refinement to other institutions is initiated. While narrow support for a theory in a specific laboratory environment is part of the experimental method, the method also looks for similarities across environments as sources of support and refinement.

4.1 William H. Riker and minimum winning coalitions

If the defining features of public choice and constitutional political economy are the roles of institutions and self-interest as the driving forces of public sector behavior, then the first experiments can be attributed to William Riker (Riker 1967; Riker and Zavoina 1970). His methods and theory were influenced by game theory and the study of coalitions in games, including experiments in sociology and psychology. His use of laboratory experimental methods was a natural step towards developing what he viewed as positive political theory as opposed to a normative approach based on political philosophy.

His focus was a three person bargaining and coalition formation in a “divide a dollar” task, a game with transferrable utility. He studied whether or not the theory of minimal winning coalitions would receive support as opposed to alternative theories of political behavior based political philosophy and the possible suppression of self-interest to norms of behavior and group cohesion. He wondered if

self-interest was a model of behavior that could be considered seriously along with models based on the psychology, sociology, and attitudes that would be called other regarding preferences in today's terminology. He studied negotiations within political institutions in which a coalition of two agents was sufficient to determine the allocation in a three person group. His results are the first to demonstrate the power of the main simple, Von Neumann-Morgenstern solution. His experiments clearly demonstrated that the principles of minimal winning coalitions could survive the test of simple environments and in doing so set the stage for the study of more complex environments.

The contrast of Riker's experiments with those conducted later is instructive. When Riker's experiments were at the formative stage neither the generality of public choice theory nor modern, laboratory experimental methods had emerged. The differences between voting theory with public goods and games in characteristic form were not recognized. Well established distinctions between a game with transferrable utility, which places a private good into the game, and those without transferrable utility, had not been fully developed. Riker's experiments were based on transferrable utility and thus, the excludability property of private goods, as opposed to public goods. Similarly, the possibility of inducing preferences for an abstract pattern of public goods was completely unknown as was the logic that would motivate such methodology. Riker did not study the detail of voting rules, and given his parameters majority rule equilibrium did not exist.

Of course, the absence of details that became known later does not detract from his contribution. His experiments were steps toward introducing experiments with game theory into political science, and toward demonstrating that positive political science was possible. In addition, he created a presumption that self-interest and individual optimizing behavior could play a role in the collective decision process as opposed to theories based solely on individual's regards for others. Not only did he legitimize the question, his results suggested the answer.

4.2 Committee experiments: equilibration

The committee experiments of Fiorina and Plott⁸ first conducted in the fall of 1972, represent a transition in substance and methods. The experimental setting was a world of public goods of the type I had studied theoretically, which differed substantially from previously conducted experiments with markets and games. In addition, new experimental methods were developed to accommodate the Fiorina and Plott discovery that a theory, which was expected to have no explanatory power even under the best of conditions, is actually very powerful. At the time of the discovery, theories of public choice were not developed with the precision needed for experimental testing and of course, no history of similar experiments existed on which to build. New methods were required to pursue the implications of the discovery.

The new experimental methods developed by Fiorina and Plott reflected hints found in the experimental methods developed in the early 1960s and used by Smith to study markets (1962, 1964). Smith employed monetary incentives to induce

⁸ Fiorina and Plott (1978).

preferences⁹ over private goods. However, public goods and associated institutions differ dramatically from private goods, especially in a world where private goods and bilateral trades do not exist. The study of committees and public choice required a substantial generalization of the methodology of induced values in order to accommodate the wide ranging motivations and institutions that the theory includes.

The methods developed by Smith were based on each person having values for only a single unit of a single good¹⁰ and required that the relationship between money and the unit exchanged was necessarily quasi linear. The value of the single unit could only be positive (no satiation). The experiments were based on the concept of exchange between two people that could take place without the knowledge or interest of others (no forced consumption and no capacity for multiple party agreements).

A world of public goods has none of the convenient features that support the use of experiments with private goods. A new approach to preference inducement was needed. Not only do institutions and procedures differ from markets, the properties of preferences that can exist in a world of public goods are completely different from those that exist in markets. Properties of public goods include multiple units, negative marginal utilities (public goods are not always good), possible non-convex preferences and synergies that can lead to complements. Other regarding preferences, including attitudes or fairness, can be at work. In general, the inducement methods cannot depend on the existence of the private good needed for quasi linear utility implementation. In a world of public goods, all individuals “consume” the amount of the goods that exist so the commodity space must be such that a change in the consumption by one person is accompanied by an identical and simultaneous consumption change by all. Indeed, considerable research had focused on the technology and commodity space of public goods, externalities and the exclusion principle (Meyer and Plott 1975). Furthermore, multiple parties are participants in changes so institutions require discussions of options so a common language must exist to support communication about options.

The new experimental methodology is deceptively simple and is illustrated in Fig. 1. The possible alternatives (the commodity space) are the points in the two dimensional plane. All preferences are induced for the points on this commodity space (the plane) which is common to all participants. That is, if the existing option is some point x on the plane, then all preferences (payoffs) are evaluated at x . For example, consider a single individual who has the preference induced by the dot at the far left in Fig. 1 (the approximate point is (25,72)). For any individual with the

⁹ Induced value refers to the use of money to induce preferences for an abstract set of options. The resulting preferences over abstract options become parameters for models applied to the choice from the options.

¹⁰ Williams (1973) attempted to expand the method to multiple units but could do so only through the use of a special trading process. Similarly, a 1973 Purdue dissertation by Harvey Reed attempted to study the two unit case but inadvertently found it necessary to change the trading process. The induced preference method had not been generalized to deal with multiple markets and certainly not with complements and substitutes among variables. The issue can be made clear through a comparison of preference inducement in the market experiments of Smith (1962) and Smith (1964) with the generalization placing value on marginal changes associated with multiple units in a single market introduced at Plott and Smith (1978), or the generalization to preference interdependence in multiple markets (Forsythe et al. (1982).

preference represented by that dot, the point (25,72) is the most preferred alternative from among all possibilities. If the alternative (25,72) is the group choice then the individual who has the preference would receive the cash represented by the dot, say \$50.00, which would be known to that individual and no one else. If, for example, the individual's preference for alternatives decreases with distance from the optimal, then the indifference curves would be concentric circles centered on the optimal. Each indifference curve could be given a label indicating the amount of money the individual would receive if the group choice is a point on the indifference curve. So long as the group decisions are restricted to the points on the plane, no side payments, deals for meeting afterward or physical threats, the individual's preferences for the points on the plane are induced and known.

Since the points on the plane are public goods, the "consumption" is the same for all participants but individual preferences for those points need not be the same. A point on the plane chosen by the group is the same point for all, and all but different preferences can be induced for different individuals. That is, if the group choice is say (40,70), then all participants get the payment indicated by their personal, induced preference at the point (40,70). The commodity space is common to all subjects, so all "consume" the same quantity of the public goods, but all can assess that quantity according to their own value using their private utility map, which can differ across individuals. Differing preferences induce the natural conflict among people regarding the choice of the public goods. Notice that the structure does not depend on the classical notion of a characteristic function from the theory of cooperative games. The decision by the group is experienced by all and there is no natural way of punishing those not in a coalition or excluding non-members from the benefits of a coalition. Thus, the structure of a public goods environment is different from the structure of a cooperative game without side payments and without transferrable utility.

Several features are worth note. First, the incentive sheets are independent so payoffs can be private and the level of payoffs can differ dramatically across subjects, even with the same preference by simply choosing different monetary magnitudes to attach to indifference curves. Indeed, while money is convenient, the source of motivation need not be the same across subjects as long as it is something that is an adequate, positive reward from the point of view of the subject. Payoffs need not be convex or continuous. Multiple units of multiple goods can be the studied. Indifference curves can be any shape desired for purpose of the experiment. Marginal utilities can be flat, positive or negative, since public goods need not be good. The public goods can be complements with synergies, substitutes or reflect lexicographic preferences.

For emphasis, the reader should notice that no private goods exist in the example in Fig. 1 and that preferences are induced for multiple units of two public goods. Five people are to choose levels of the two public goods and conflict exists among them. Prior to this technique, experiments without private goods had not been conducted and there had been no market experiments with multiple commodities and multiple units of commodities. Such features were not possible given the experimental techniques that had been used in economics or in political science.

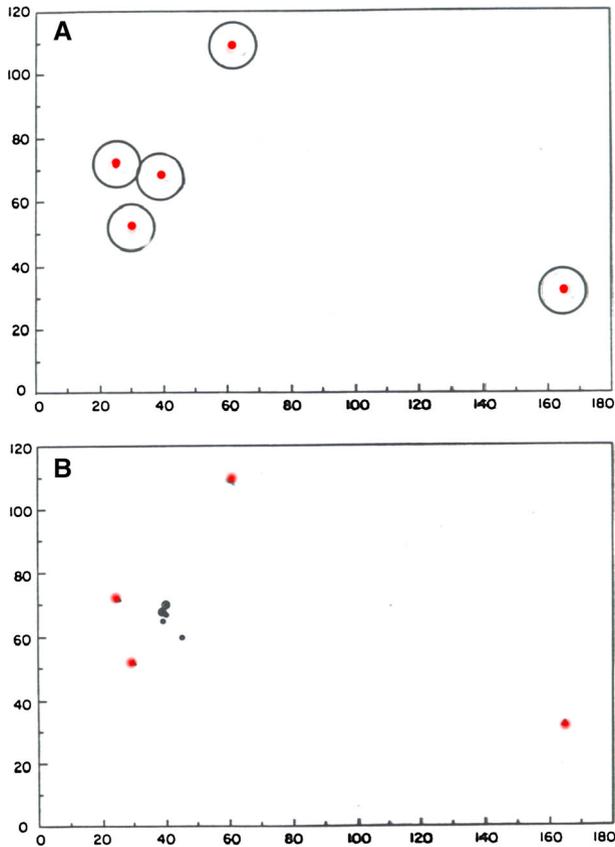


Fig. 1 a Preference parameters five person. b majority rule committee decisions

The new environment and theory created new challenges that Fiorina and Plott met by changes in the experimental techniques but also changes in the application of and logic of experimental methodology. The traditional experimental methodology of theory testing and rejection seemed incapable of moving the theory in useful ways. The abstractness and fragility of the theory combined with the absence of operational constraints and institutional detail made the theory a trivial target for rejection. It was easy to imagine experiments in which the theory could be rejected. Other general theories of group decisions found in psychology and game theory were similarly vague or incomplete and thus suffered from the same vulnerability. Simple theory rejection seemed to give little insight about any explanatory power that might exist and how it might be improved by experimental methods. The methodology of “theory test” experiments relied on the existence of theories that were much more precise than the public choice and political theories available at the time.

The challenges were overcome through two methodological changes. First, the experimental approach was inverted from the traditional “theory first” method to a “data/phenomena” first method. The traditional approach starts with theory, implements experimental controls that satisfy the conditions of the theory, and then

asks whether or not the theory is true or false. By contrast, the Fiorina and Plott approach started with an experimental environment constructed to study simple cases of phenomena that public choice theories were attempting to explain. The logic that supported the use of experiments was simple and directed by the “fundamental equation”. General theories should work in simple and special cases. The purpose of an experiment is to take a look and assess what, if any, of the phenomena the model captures. The idea is that if the models fail to “work adequately” in the easiest cases, then one would not expect them to work to explain more complex cases. On the other hand, success when applied to the easy is an invitation to explore theory generalization and increasing experimental complexity.

Given the experimental environment, the second methodological change was an empirical focused on which of several models might produce the best explanation for the data, even though the experimental controls might not meet the assumptions of any of the models. It is a contest among theories as opposed to the test of a theory and allowed research to expand as guided by the most promising models while remaining consistent with a set of basic principles. The phenomena chosen for study were the decisions of committees that operated with specific, well defined rules in which participants had well-formed preferences about a set of options without uncertainties and without information about the preferences of others. Multiple models reasonably could be applied to such an experiment so rather than studying the prediction of one theory, they computed the predictions of many theories. The question was changed from “is the theory true” to “which theory/model best explains the data”,¹¹ and how the model might be improved. This change required developing a technique for determining the “best” from among several competing theories.

The mathematical elegance of equilibrium theory suggested that generalizations were possible but such generalizations would not be of interest if the equilibrium theory could not work under the best of conditions. Scientific interest in the theory and any of its generalizations would be dictated by the experimental results as opposed to its logic or potential applications that might be imagined. That was a new type of argument that flowed directly from the methodology implicit in the fundamental equation. In addition, the public goods environment permitted experiments that simultaneously tested many competing theories¹² and also set the stage for the study of the broad range of public choice institutions and theory that exist outside the world of private goods and markets.

The Fiorina and Plott experiments and subsequent extensions, demonstrate the existence of an equilibration process in voting groups. Figure 1a contains an illustration with five voters and circular indifference curves centered at a dot encircled by a typical indifference curve. The world is one with only public goods. A unique voting equilibrium exists at the maximum for the individual located at the

¹¹ The approach is influenced by Bayesian methods in the sense that it is not meaningful to reject a theory without having an alternative. However, the absence of a theory of error structure presented a special challenge.

¹² The Fiorina and Plott experiment tested sixteen competing behavioral models within the single experimental setting. Several of the theories were found in the social psychology and sociology literature. Others were found in the political science literature and still others were found in the Public Choice and Economics literatures.

interior of the Pareto Optimal points. Early experimental work focused on both the voting procedures and the underlying structure of the alternatives. If the voting follows a form of Roberts Rules of Order and if underlying set of alternatives has a spatial structure in which the equilibrium exists, then the committee decisions accumulate near the equilibrium as shown in Fig. 1b. The tendency of equilibration illustrated in the figure has been replicated many times and under a variety of preference configurations. The experiments demonstrate that a principle of equilibration exists in such environments.

The discovery that an equilibration tendency could be observed in an experimental environment led to an explosion of ideas even though the equilibration had been observed in only a narrow class of environments. The result suggested the need for many different experiments to explore the robustness of the phenomena and the sensitivity to institutions. The broad ranges of public choice questions were immediately open. The implications the fundamental equation are unbounded and new possibilities were exposed. Figure 2 contains a self-explanatory map of experiments proposed in the Fiorina and Plott proposal to the National Science Foundation developed in the summer and fall of 1973 and submitted late that fall.¹³ It is interesting to note that a large part of the proposed research was related to experimental procedures and methods. However, an equally large part was focused on institutions, which clearly reflected the influence of Jim Buchanan and what would be latter be called the constitutional political economy strand of Public Choice research.

Of course, the fragility of existence of the equilibrium was an invitation to theory refinement and additional experiments. Fiorina and Plott studied the case where no equilibrium exists by moving the maximum of the person at the equilibrium in Fig. 1a slightly down and to the right. The outcomes in the resulting non-equilibrium experiments found a clustering of outcomes similar to the equilibrium experiments, albeit the outcome cluster of the non-equilibrium experiments was broader than the equilibrium experiments. Nevertheless, the outcomes were not scattered throughout the possibilities and thus, suggested the existence of some as yet unformulated equilibrium/solution concept. None of the existing theories worked well to predict what happens, a fact that created a challenge.¹⁴

¹³ The initial experiments were all funded by an earlier NSF grant to C. Plott. By the spring of 1973, many of the Fiorina and Plott experiments were completed and the research was focused on new directions.

¹⁴ The case of non-equilibrium was not studied until after September 1973 when the first agenda experiments were conducted. Both Mo and I wanted to do the non-equilibrium environment but could not find a justification in terms of an understanding for what would be learned. In frustration, Mo asserted "If we move the equilibrium and if the data just follow the maximum of the interior person, it would be very embarrassing." That comment together with the agenda theory, which had just been exposed by the flying club exercise of Plott and Levine (1978), supplied a theory. If the agent in the center proposed his/her maximum at some point, a plausible agenda step exists that could lead to the point. Thus, the agenda experiments provided a theory about what might be expected if the equilibrium did not exist. It was the justification we were seeking and the experiments were conducted. Interestingly, exactly why we were excited about the research was not obvious to everyone. Vernon Smith arrived at Caltech in the fall of 1973 and, after observing what Mo and I were doing, asked me in a somewhat rhetorical tone, why we were doing such research, which was obviously dramatically different from what had taken place in economics and made little sense to him at the time. Mo and I knew that we were going to have a difficult

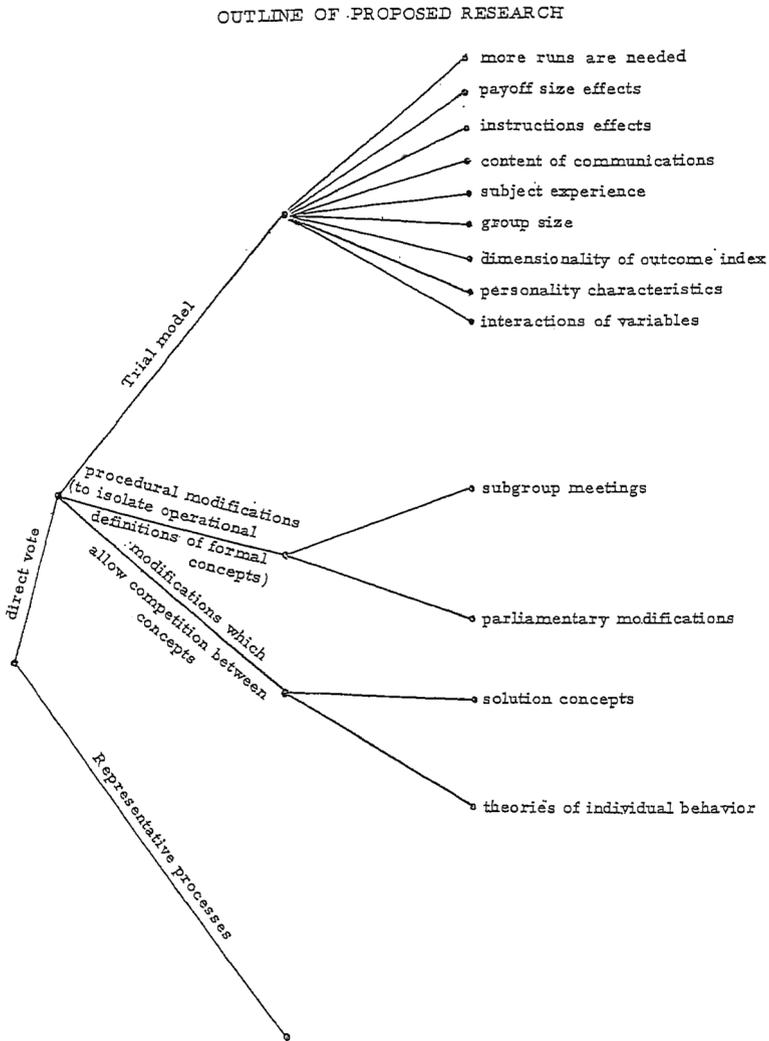


Fig. 2 Induced preferences for two public goods and experimental outcomes for majority rule choice of public goods

What theory describes outcomes when the equilibrium does not exist? Many theories and tests have emerged over the intervening decades. Indeed, all branches of Fig. 2 have been explored and continue to be explored. Among the first that attempted to replicate the Fiorina and Plott results and generalize the theory to cover the cases of non-equilibrium was developed by Richard McKelvey and Peter

Footnote 14 continued

time explaining what we were doing to a very skeptical audience. Vernon's comment suggested that it would be harder than we anticipated. Except for those very close to public economics and public choice the source of excitement and curiosity was not obvious.

Ordeshook¹⁵ who also explored parliamentary procedures such as an accumulation of amendments and associated votes before voting on a single motion. Their model draws heavily on classical cooperative game theory in which coalition formation is a central feature of group decision. Like Riker, the McKelvey and Ordeshook, “competitive solution” has coalitions forming and coordinating to achieve a purpose while minimizing concessions to those whose agreement is not needed for achieving the goal. As a prediction, the competitive solution presents a challenge in terms of uniqueness but in the experiments for which clear predictions could be deduced, the data follow the patterns predicted.¹⁶

4.3 Alternative voting rules: the power of veto

The Fiorina and Plott results suggest that successful models focus on winning and blocking coalitions in relation to pairs of alternatives. That fact is clear in retrospect now, after decades of experiments. The principle that operates can be seen in the power of the veto. An alternative x dominates an alternative y if a winning coalition unanimously prefers x to y . A blocking coalition is a subset of all winning coalitions and thus, has “veto power” in the sense that x does not dominate y if the blocking coalition is not unanimous for x over y . The outcomes predicted by the model are the undominated alternatives, which always exists if blocking coalitions exists.¹⁷

Unanimity as a voting rule places all voters in the position of a veto player. No doubt this is the feature that made the process attractive for Buchanan. His continuous exploration of such rules over the years served to give the method of unanimity high priority in experiments. Figure 3 adapts the environment typically used in the study of majority rule by a simple change of the voting rule from majority rule to unanimity. The status quo from the majority rule committees is retained as are the other procedures. The only change is that the final vote and amendments to a motion on the floor must be accepted by a unanimous vote as opposed to a majority. The notion of equilibrium used in majority is also defined in terms of a point from which no change can receive the needed vote. The set of equilibria under unanimity is the set of Pareto Optimal options according to the equilibrium notion that emerged from my first examination of the world of all public goods. The data are shown in the Fig. 3. All outcomes are in the set of Pareto optima. Inefficient decisions are never made. Interestingly, the data are clustered near the center of the Pareto Optima.¹⁸ The reason for the attraction to the center is unknown. While the default outcome is important, both fairness and expectations about what others might accept are speculations about the underlying principle that operates.

¹⁵ Berl et al. (1976).

¹⁶ McKelvey and Ordeshook (1978). See also, Laing and Olmsted (1978).

¹⁷ Early experiments pitted a Von Neumann–Morgenstern solution against the core. The issue was whether the VM solution captured data that the core would not. In particular, the experiments are asking if coalition theories had predictive power over equilibrium theories. If the committee operates by rules similar to Robert’s Rules, the answer is no.

¹⁸ See Levine and Plott (1977) and Plott and Levine (1978).

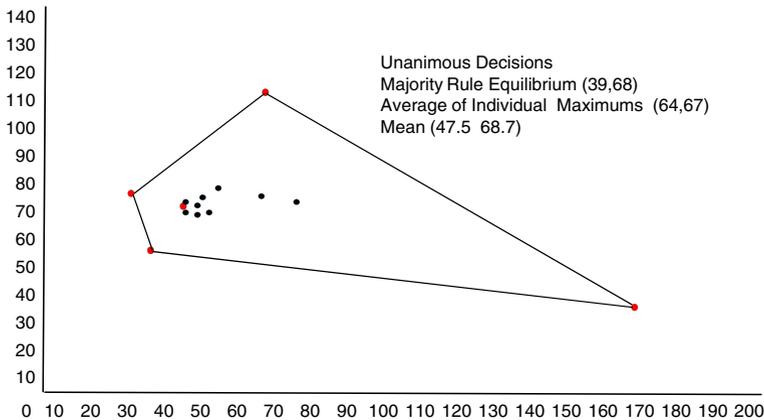


Fig. 3 Outline of possible experiments motivated by the Fiorina and Plott results

The power of the general model and the central role of the concept of blocking, is easily illustrated by committees that operate under closed rule, in which a specific individual or subcommittee has the power to prevent votes on alternatives.¹⁹ However, that individual or subcommittee cannot implement any alternative unless joined by a majority. The members of such a subgroup are viewed as “veto players” in the sense that x cannot be chosen over y if the coalition of veto players does not unanimously prefer x over y . In the language of the theory, y is not dominated by x . A set of alternatives that has the property of being “undominated”, the core of an appropriately defined cooperative game without side payments, tends to attract the outcomes of committee choices.

In Fig. 4, the individual at the right of the figure has the power to prevent votes on any proposal but cannot make proposals and a proposal on which a vote is allowed cannot win unless it is accepted by a majority of those voting. The voter is a veto player. The majority rule equilibrium without the veto player is the point in the center of the Pareto Optima as was represented in Fig. 1a. But, if a veto player exists, as is the case in Fig. 4, the core of a social choice game without side payments, the undominated alternatives, are those that exist on the line connecting the majority rule equilibrium and the maximum for the veto player. The dots in the figure are the actual committee choices in experiments. As can be seen, the committee choices are scattered in the direction of the core. Thus, the shift to what is effectively the closed rule also shifts the equilibrium from the single point to the line segment. Notice that the undominated options, the core, become an effective model of committee choices. The use of veto players can be extended to capture complex political systems and experiments support the model as effectively predicting group choice. It is important to note that if the set of options contains cycles, the most preferred alternative of the veto player is always in the core and if the cycles are sufficiently numerous the core shrinks to the optimum of the veto

¹⁹ The closed rule was first studied experimentally in Isaac and Plott (1978).

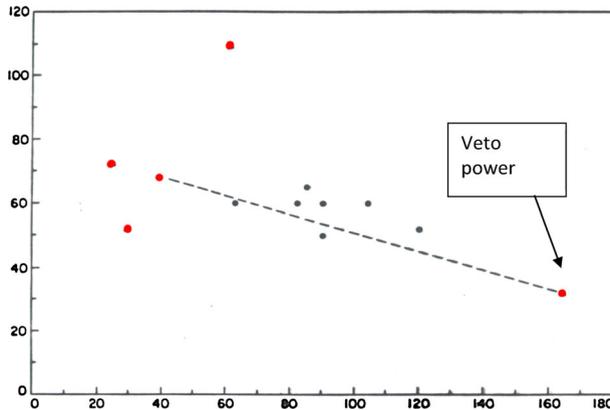


Fig. 4 Closed rule—majority rule with a veto player

player. In that sense, the veto player has considerable power. That fact also answers a long-standing question about the absence of observed cycles in ongoing political systems. If veto players exist, then an equilibrium always exists. This fact also addresses questions about the fragility of the majority rule equilibrium. Frequently observed institutional features of systems can add stability to the system.

4.4 Agenda theory and design as a method and purpose

The results from spatially embedded committee processes operating under versions of Roberts Rule suggest optimism that general principles from cooperative game theory operate to determine the outcomes of all committee processes. Unfortunately, agenda theory dashes such hopes. While the core of the appropriate game is an extremely powerful model for some environments, the agenda experiments demonstrate that the power does not extend to all environments.

An agenda is a sequence of partitions of the alternatives produced by a series of agenda questions. For example, if the set of options is $\{A, B, C, D\}$, the first question could pose a choice between the sets $\{A, B\}$ and $\{C, D\}$. The second question would apply to the chosen set and ask which of the two options will be selected as a final choice. Language is sufficiently versatile to induce very natural sounding agenda. For example, the proposal to “consider the extremes first” pits the set $\{A, D\}$ against the set $\{B, C\}$. The outcome of the deliberations will differ according to the sequence of proposals. Agenda theory suggests that the alternative finally selected can be substantially determined by a properly designed agenda. It is important to recognize that this power of the agenda is unrelated to voting cycles.

The theory of the agenda and the power of the agenda to influence groups was first discovered by Plott and Levine. They developed and explored the topic in both experimental environments and in a field application in which a large flying club was influenced to buy a fleet of planes preferred by the person in charge of the agenda.²⁰ The application had two impacts. First, it demonstrated the power of

²⁰ See Levine and Plott (1977) and Plott and Levine (1978).

public motivated theories when applied to complex, “real world” controversies and the central role of experiments in such applications. Secondly, it changed the institutions on which the theory was focused.

The fact that the influence of the agenda does not depend on voting cycles is underlined by the fact that it can exert systematic influence even when all members of the group have the same preference over alternatives. According to theory, the agenda works by keeping voters in the dark at every stage, not revealing what might be the outcome of the vote in subsequent stages and preventing discussions and straw votes that reveal what might happen in subsequent stages. Voters tend to be a bit random between being optimistic, expressing their preference for the set with their most preferred option, and pessimistic, voting against the set that contains their least preferred. The predictable randomness together with any diversity of preferences that might exist in the group, can be used to fashion the agenda such that at each stage of voting the options not preferred by the agenda designer are eliminated. The objective is to have only the option preferred by the designer remains after the voting.

Thus, agenda experiments demonstrate that the undominated alternatives that are such a powerful model in the spatial environment with Roberts Rules of Order cannot be applied with abandon to predict group choices. The agenda theories demonstrate that naturally appearing agenda, if imposed, can induce voting groups to choose almost anything. Thus, procedures can be used to cause outcomes to be different from the core or any other game solution.

Agenda research also created a methodological advancement for experimental research. In particular, the research introduced the methodology of design in which the research purpose is not only the testing of theory but is also asking if institutions can be designed to serve some purpose and if so, what might be the role of experiments. Clearly, the power of institutional design was known to public choice and axiomatic social choice scholars long before the modern theory of mechanism design was introduced. Indeed, the constitutional political economy strand of public choice emerged because of an understanding of the power of institutional choice. The key steps to creating a useful methodology were used by Levine and Plott.

In today’s language, the steps are: (1) Does the mechanism do what it is supposed to do—proof of principle; and (2) Does it do it for the right reasons—those that led to the design—design consistency. That approach was explicitly used in explaining the role of the agenda experiments.

4.5 Externalities and public goods provision: efficiency measures and the intersection of public and private sectors

In a world of only public goods, no efficiency measures exist other than Pareto Optimality and if the institutions contain veto players the outcomes will tend to be Pareto Optimal. Measures of gains from trade require a private good and thus the efficiency measurement of institutional performance in an experiment requires a private good. The modern measurement of efficiency in an experiment was discovered and applied to classical market environments by Plott and Smith (1978). Their measure of efficiency is the total gains from trade—the actual money gained

by participants as a group divided by the highest total possible. Their measure allows experiments to assess the extent of “market failures” and responses to institutional changes. And, it can do so even if the theory responsible for the institutional impact is not understood. This insight allows assessment of institutions based on experiments even when the theoretical implications of competing institutions is not fully understood.

Subsequent experiments demonstrated that markets can operate at near 100 % efficiency in this sense, which stimulated the broad expansion of experiments on policy and market related institutional design.

Two primary theories of market failure, externalities and public goods, are often used to motivate public policy. Both follow from the hypothesis that preferences need not be “other regarding”. Externalities lead to market failure if people do not incorporate the damage done to others by their private behavior. Public goods provision fails because of the possibility of free riders, again a type of unresponsiveness to the preferences of others. Whether or not market failures actually exist or what might be done if failures do exist, depend on what is accepted about the pattern of preferences and the behaviors that follow. Neither introspection about own preferences nor historical examples seemed to produce evidence supporting generalization. Data are needed.

Very early experiments demonstrated that externalities produced in a market environment induced behavior substantially as theory predicted.²¹ Subjects participated in a traditional double auction but every trade by any trader created a penalty imposed on all others. The trade undertaken by any pair of participants created an externality (the penalty was a cost per unit traded by anyone in the market—a social cost) that applied to all others as soon as the trade took place. The insight and experimental methodology was developed from the methods developed to study committees merged with the methods used to study markets. The markets with externalities converged to the same competitive equilibrium as would have been the case if no externality had been imposed. Because failure to trade can be interpreted as a contribution to the public good of penalty (social cost) reduction, the trades themselves can be interpreted as the failure to contribute to the provision of the public good. Thus, those who traded in the externality environment can be viewed as first “free riders” and a demonstration of the free rider phenomena related to the theory of public goods. Experimental variations, imposing a tax and creating a permit corrected the externality as expected, raising efficiencies to near 100 %, using the Plott-Smith measure of efficiency. The results have remained uncontroversial.

Research related to the provision of public goods emerged from multiple literatures with different presumptions about the problem, different methodologies and different theories. In all cases, the initial experiments suggest that public goods provisions are not characterized by total free riding and that the problem might not be as severe as theory suggests. Perhaps the first was Peter Bohm who approached

²¹ Plott (1983). The paper was circulated as: Social Science Working Paper 180, California Institute of Technology, 1978. As was typical of experimental papers in those days it took years to get research published.

the issue as a measurement problem and investigated the willingness of individuals to pay to watch a TV program.²² Different questions and circumstances were examined. His general conclusion was the people are more willing to contribute than the literature would lead you to believe.

Psychologist, Robin Dawes and colleagues initiated other experiments they interpreted as social dilemmas. A variety of institutions had unanticipated effects on contributions to a public good.²³ Group size, feedback, and instructions were varied in an attempt to find conditions that influence group contributions. While individuals had a dominant strategy to free ride, contributions persisted at significant, but inefficient, levels that could be influenced by procedures. Sociologists Gerald Marwell and Ruth Ames also conducted experiments²⁴ with the same overall pattern of results. Under the conditions of those experiments, people do not simply start free riding and stay there.

Economists attracted to the public goods problem seemed to start with the presumption that free riding would be frequent, if not pervasive, and concentrated on institutions and “mechanisms” that would induce the group to implement the optimal levels of public goods. Ferejohn et al. explored a mechanism to induce payments for public broadcasting programs.²⁵ Vernon Smith examined several mechanisms for public goods provision.²⁶

The studies of public goods provision mechanisms produced levels far above the zero level predicted by free riding. However, these studies lacked any baseline that would establish the levels of public good provision that would occur in the absence of the mechanism. In fact, substantial free riding on public goods provision had never been observed. The public goods provision mechanism studies demonstrated a possible solution to a problem that might not exist. Experiments were needed that could establish conditions under which free riding will be observed, if indeed such conditions exist. Interestingly, even after years of theory that assumed the pervasive existence of free riding in the provision of public goods, the phenomena had not been experimentally observed.

A substantial research gap existed. Theory predicted the existence of free riding. Public goods provision mechanisms were constructed on the presumption that free riding needed correction. Yet, free riding had not been observed and a body of opinion existed that suggested that free riding is against human nature and thus, would never exist. The experimental gap was filled by two studies focused on sufficient conditions to get free riding. Isaac, McCue, and Plott were the first to observe public goods free riding. Their experiments were motivated by intuition drawn from the public choice literature and behavior observed in markets with externalities. They studied an environment with different, declining values for a

²² Bohm (1972).

²³ Dawes (1975), Dawes et al. (1977).

²⁴ Marwell and Ames (1979), Marwell and Ames (1980), Marwell and Ames (1981).

²⁵ Ferejohn et al. (1979).

²⁶ Plott and Smith (1978); Smith (1979); Smith (1980).

public good that must be sustained by repeated contributions.²⁷ Kim and Walker followed quickly and observed free riding in a similar environment.²⁸ In both cases, initial high levels of contributions declined rapidly to very low levels of contribution, which can be interpreted as free riding with occasional “pulses” in contributions as isolated individuals attempted to solve a problem what was obvious to them but could do nothing about.

These studies set the stage for tests of institutional solutions by discovering environments in which the natural level of public goods provision is low, thereby giving institutions a substantial hurdle to overcome. In the language used now, these environments can be used to “stress test” newly designed public goods provision mechanisms. The question posed was whether or not new types of institutions suggested by the Public Choice approach would successfully improve public goods provision in environments where public goods provision would not otherwise take place. In the decades that followed, the experimental study of public goods mushroomed.

4.6 Policy application of laboratory methods: institutions for airport access

Experimental methods in public choice passed another important landmark with the first application to an active policy issue²⁹ that took place during the process of airline deregulation in the mid-1970s. The background of the application was based on the development of agenda theory and the application to the flying club, which had proved feasibility of laboratory based policy research.

Airport’s access at four major airports was controlled by committees, “slot committees”, populated by the airlines that operated at the airport. The traditional function of these committees was coordinating the arrivals and departures of aircraft, the time “slots”. The number and general pattern of slots were authorized by the Civil Aeronautics Board (CAB). Historically, the CAB allocated the rights to operate over routes, the scheduling of operations and setting of rates. Deregulation would remove CAB authority leaving the slot committees as the process for determining airport access. The CAB was concerned that the committees could function as a barrier to entry and perhaps also as a facilitating device for deeper anti-competitive activities. The power of the procedures used by the committees had been fully demonstrated by the Levine and Plott flying club example.

²⁷ In essence, the needed conditions were already known from the behavior of markets with externalities. A reduction in consumption or production of an external diseconomy is a contribution to the public good of external diseconomy reduction. Such contributions were not forthcoming in the externality experiments of Plott (1983) so the issue just turned on understanding the relationship between a positive contribution to the public good and the restraint of making a contribution to a public bad.

²⁸ Isaac et al. (1985), Kim and Walker (1984).

²⁹ An earlier policy application in economics was a paper by Hong and Plott (1982) who conducted a study on rate posting for the U.S. Department of Transportation. That study had an effect on the policy but the DOT did not publish the study due to the fear that Senator Proxmire would grant the DOT his “Golden Fleece” award for wasteful spending. Interestingly, the long delay in the publication of this first application is not an isolated example of the difficulties getting early experimental work published.

The CAB commissioned a study of the slot committees to determine how the committees functioned and to explore alternatives to the committees.³⁰ The committees used the rule of unanimity to make decisions. The process started with proposals based historical allocations followed by concessions and changes proposed by the individual carriers. The report studied the committee procedures, deliberations, and decisions. From the study, it became clear that committee members believed that in the event of a failure to reach unanimity, the allocation of slots would be a political process that could involve members of Congress. It was also believed that the default process would exert pressure on the large carriers to make slots available to new airline entrants and to smaller carriers.

The analysis of the slot committees involved experiments with committees operating under conditions similar to the slot committees and also involved experiments with recommended alternatives. The purpose of the experiments was to illustrate the nature of the underlying principles at work under the committee processes. Specifically, if the default is equal splits, then the core of unanimity voting game includes equal splits. The implication for committees with a pattern of initial endowment similar to the existing airline endowments is unambiguous. The larger holders give up slots to smaller participants.

This implies that committee-based allocation can substantially reduce efficiency by inducing large, efficient holders to give up slots to small, inefficient holders. By contrast, efficiency calls for the efficient holders to grow in size while inefficient holders shrink. The committee experiments demonstrated the power of the core through experiments that manipulated endowments and efficiency and demonstrated that the committee choice was dictated only by the equilibrium. The process had no sensitivity to any dimension of efficiency.

Examination of data from multiple years of slot committee decisions demonstrated that the slots held by the large carriers were eroding over time. The slots given up by large carriers were transferred to new entrants. Committee discussions recorded as part of the study found a similar process as small carriers and midsize carriers, who had no interest in giving up slots to small carriers, pressured and threatened the larger carriers with the prospect that the larger carriers could suffer greater losses than those required to facilitate a unanimous choice. The fact that the larger carriers almost never grew and the smaller entrants were never denied a few slots suggested that the actual allocations were characterized by the inefficiencies predicted by theory and experimental evidence. Comparisons of experimental results to the actual committee decisions suggested that the same principles were at work in both places. Once the core was understood, its applicability became obvious.

The carriers immediately lost faith in the committees. The study recommended that the slots be auctioned or that existing carriers be grandfathered with slots bought and sold. The latter system ultimately replaced the committee system. The experimental auctions are of interest as the first combinatorial auctions and approached the allocation as a sequence of auctions.

³⁰ Grether et al. (1979). The report was subsequently published as a book: Grether et al. (1989).

The application to an on-going, politically charged policy issue demonstrated that the laboratory results could be (carefully) applied outside the laboratory and demonstrated by example of how that can be done when the scale is large and visible. The data from the laboratory related to theory in much the same way that data from the field related to theory. The theory itself made sense and was readily accepted by those close to the policy issue. Furthermore, the application established the capacity of the laboratory methods to withstand public scrutiny. That issue of institutional design would be present in the first policy application of laboratory methods is not surprising. The design of institutions was a public choice theme from the beginning. Institutional comparisons were natural as was the use of efficiency measures as a norm of comparison.

5 The decades that followed

The first years of the 1970s were almost completely dominated by Public Choice experiments and were heavily influenced by theories of committees and social choice processes. A merger of public choice experiments with market experiments begins slowly in 1974 when Vernon Smith visited Caltech (1973/74) and then rapidly advances with new experiments applied to market uncertainty (Plott and Wilde (1982), information (Plott and Sunder (1982, 1988), time interdependence (Forsythe et al. 1982) and institutions. Similarities in the importance of institutions in both markets and public choice (e.g. Nash equilibria and core—like principles together with their limitations) began to be recognized. At the same time, a second merger was taking place between public choice experiments and axiomatic social choice. The merger took axioms used to explore philosophies of social preference and reconstructed them in terms of the behavioral concept of a dominance relation of cooperative games without side payments. The new tools from social choice theory added solution concepts from cooperative game theory without side payments and facilitated the inclusion of institutions without the complicating detail required by non-cooperative games and Nash equilibrium (Plott 1976).

By the beginning of the 1980s, the interrelated disciplines of economics, political science, and public choice had a solid laboratory experimental foundation. Key principles had been established. The methodology of design and experimental testing as a policy exercise was understood and successfully applied. The few examples convincingly demonstrated that the basic research could ultimately produce value in applications. The avalanche of research in the following decades was clearly anticipated by the early period of work. Public Choice and constitutional political economy remain at the center of the scientific developments.

The development of experiments in the early 1970s was driven by curiosity about the power of institutions to shape collective choice, much of which was stimulated by the work of James Buchanan and Gordon Tullock together with the broad issues of public choice and political science. Paradoxically, in spite of his influence, experiments did not move to study Buchanan's major interest: constitutional choice. How will individuals design and choose institutions and will participation in that process influence their behavior? The early experiments were narrowly focused on

behavior within institutions given a fixed set of options and well-formed individual preferences.

Institutional preferences motivated by self-interest are understood and can be observed as individuals manipulate institutional designs to advance personal ends. However, the deep questions about the principles of behavior that operate at the level of constitutional choice remain open. The time and cost of such experiments might be a challenge, but intellectual and scientific promise loom large. How might an experiment avoid the regress of institutions to choose institutions? What preferences should be induced and what is the role of uncertainty? The thoughts of Jim Buchanan and the blossoming field of Constitutional Political Economy include many hypotheses about what the answers might be.

Acknowledgments The comments of Roger Congleton, Morris Fiorina, and Andrej Svorenecik are gratefully acknowledged.

References

- Berl, J. E., McKelvey, R. D., Ordeshook, P. C., & Winer, M. D. (1976). An experimental test of the core in a simple n-person cooperative, non-sidepayment game. *Journal of Conflict Resolution*, 20(3), 453–479.
- Black, D. (1958). *The theory of committees and elections*. Cambridge: Cambridge University Press.
- Black, D., & Newig, R. A. (1998). *Committee decisions with complementary valuation*. (Revised second editions, edited by I. McLean, A. McMillan, & B. Monroe). Kluwer.
- Bohm, P. (1972). Estimating demand for public goods: An experiment. *European Economic Review*, 3(2), 111–130.
- Dawes, R. M. (1975). Formal models of dilemmas in social decision-making. In M. Kaplan & S. Schwartz (Eds.), *Human judgment and decision processes* (pp. 87–107). New York: Academic Press.
- Dawes, R. M., McTavish, J., & Shaklee, H. (1977). Behavior, communication and assumptions about other people's behavior in a commons dilemma situation. *Journal of Personality and Social Psychology*, 35(1), 1–11.
- Downs, A. (1957). *An economic theory of democracy*. New York: Harper.
- Ferejohn, J., Forsythe, R., & Noll, R. (1979). In C. D. Russell (Ed.) *Practical aspects of the construction of decentralized decision-making systems for public goods*.
- Fiorina, M. P., & Plott, C. R. (1978). Committee decisions under majority rule: An experimental study. *American Political Science Review*, 72(2), 575–598.
- Forsythe, R., Palfrey, T., & Plott, C. R. (1982). Asset valuation in an experimental market. *Econometrica*, 50(3), 537–567.
- Frisch, R. (1959). On welfare theory and pareto regions. *International Economic Papers*, 9, 39–92.
- Grether, D. M., Isaac, R. M., & Plott, C. R. (1979). *Alternative methods of allocating airport slots: Performance and evaluation*. Paper prepared for the Civil Aeronautics Board. Polinomics Research Laboratories, Inc., Pasadena.
- Grether, D. M., Isaac, R. M., & Plott, C. R. (1989). *The allocation of scarce resources: Experimental economics and the problem of allocating airport slots*. Boulder, CO: Westview Press.
- Grether, D. M., & Plott, C. R. (1979). Economic theory of choice and the preference reversal phenomenon. *The American Economic Review*, 69(4), 623–638.
- Hong, J. T., & Plott, C. R. (1982). Rate filing policies for inland water transportation: An experimental approach. *Bell Journal of Economics*, 13(1), 1–19.
- Isaac, R. M., McCue, K. F., & Plott, C. R. (1985). Public goods provision in an experimental environment. *Journal of Public Economics*, 26, 51–74.
- Isaac, R. M., & Plott, C. R. (1978). Cooperative game models of the influence of the closed rule in three person, majority rule committees: Theory and experiment. In P. C. Ordeshook (Ed.), *Game theory and political science*. New York: New York University Press.

- Kim, O., & Walker, M. (1984). The free rider problem: Experimental evidence. *Public Choice*, 43, 3–24.
- Laing, J. D., & Olmsted, S. (1978). An experimental and game-theoretic study of committees. In P. C. Ordeshook (Ed.), *Game theory and political science* (pp. 215–281). New York: New York University Press.
- Levine, M. E., & Plott, C. R. (1977). Agenda influence and its implications. *Virginia Law Review*, 63(4), 561–604.
- Marwell, G., & Ames, R. (1979). Experiments in the provision of public goods I: Resources, interest, group size and the free-rider problem. *American Journal of Sociology*, 84(6), 1135–1160.
- Marwell, G., & Ames, R. (1980). Experiments in the provision of public goods II: Resources, interest, group size and the free-rider problem. *American Journal of Sociology*, 85(4), 926–937.
- Marwell, G., & Ames, R. (1981). Economists free ride, does anyone else? Experiments on the provision of public goods IV. *Journal of Public Economics*, 15, 295–310.
- McKelvey, R. D., & Ordeshook, P. C. (1978). Competitive coalition theory. In P. C. Ordeshook (Ed.), *Game theory and political science* (pp. 1–37). New York: New York University Press.
- Meyer, R., & Plott, C. R. (1975). The technology of public goods, externalities and the exclusion principle. In E. S. Mills (Ed.), *Economic analysis of environmental problems* (pp. 65–94). New York: Columbia University Press.
- Plott, C. R. (1967a). A notion of equilibrium and its possibility under majority rule. *The American Economic Review*, 57(4), 787–806.
- Plott, C. R. (1967b). A method of finding acceptable proposals in group decision processes. *Papers on Non-Market Decision-Making*, 2(1), 45–59.
- Plott, C. R. (1976). Axiomatic social choice theory: An overview and interpretation. *American Journal of Political Science*, 20(3), 511–596.
- Plott, C. R. (1979). The application of laboratory experimental methods to public choice. In C. S. Russell (Ed.), *Collective decision making: applications from public choice theory* (pp. 137–160). Baltimore: Johns Hopkins Press.
- Plott, C. R. (1983). Externalities and corrective policies in experimental markets. *The Economic Journal*, 93(369), 106–127.
- Plott, C. R. (2001) Public economics, political processes and policy applications. In *Collected papers on the experimental foundations of economics and political science, volume one*. Cheltenham, UK: Edward Elgar Publishing.
- Plott, C. R., & Levine, M. E. (1978). A model of agenda influence on committee decisions. *The American Economic Review*, 68(1), 146–160.
- Plott, C. R., & Smith, V. L. (1978). An Experimental examination of two exchange institutions. *The Review of Economic Studies*, 45(1), 133–153.
- Plott, C. R., & Sunder, S. (1982). Efficiency of experimental security markets with insider information: An application of rational expectations models. *Journal of Political Economy*, 90(4), 663–698.
- Plott, C. R., & Sunder, S. (1988). Rational expectations and the aggregation of diverse information in laboratory security markets. *Econometrica*, 56(5), 1085–1118.
- Plott, C. R., & Wilde, L. L. (1982). Professional diagnosis vs. self-diagnosis: An experimental examination of some special features of markets with uncertainty. In V. Smith (Ed.), *Research in experimental economics* (Vol. 2). Greenwich, CO: JAI Press.
- Riker, W. (1967). Bargaining in three person games. *American Political Science Review*, 61, 342–356.
- Riker, W., & Zavoina, W. (1970). Rational behavior in politics. *American Political Science Review*, 64, 48–60.
- Smith, V. L. (1962). An experimental study of competitive market behavior. *Journal of Political Economy*, 70(2), 111–137.
- Smith, V. L. (1964). Effect of market organization of competitive equilibrium. *The Quarterly Journal of Economics*, 78(2), 181–201.
- Smith, V. L. (1979). Experimental mechanisms for public choice. In Peter Ordeshook (Ed.), *Game theory and political science*. New York: New York University Press.
- Smith, V. L. (1980). Experiments with a decentralize mechanism for public goods decisions. *The American Economic Review*, 70(4), 584–599.
- Williams, F. (1973). Effect of market organization of competitive equilibrium: The multi-unit case. *The Review of Economic Studies*, 40(1), 97–113.