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Susan C. Athey: John Bates Clark Award Winner 2007

John Roberts

Susan Carleton Athey is the 2007 recipient of the American Economic Association's John Bates Clark Medal, which is "awarded biennially to that American economist under the age of forty who is adjudged to have made the most significant contribution to economic thought and knowledge." Her winning was somewhat surprising. After all, no woman had won before in the 60-year history of the award. Recent awards had tended to go to scholars who did less foundational and perhaps more accessible work than Susan. Also, at age 36, Susan still would have been eligible for the 2009 award. Yet at the same time, the award was not really unexpected: In the days leading up to the announcement, a journalist who was trying to predict the choice by polling prominent members of the profession indicated that Susan was overwhelmingly favored to win. Moreover, Avinash Dixit had predicted twelve years before, when Susan was a 24 year-old job market rookie, that she would be very much in the running for the Clark Medal (Nasar, 1995).

I have had the immense pleasure of being Susan's teacher, her advisor, her coauthor, and her friend. Yet I never cease to be amazed at her abilities and her accomplishments on so many dimensions. The AEA specifically cited her work in four distinct areas: monotone information models; industrial organization and particularly auctions; macroeconomics; and econometrics. Yet there is even more breadth to Susan's research contributions than this suggests, as I will show below. Further, she is an exceptional teacher, a dedicated advisor and mentor, a tireless

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Susan C. Athey

(photo credit: Tanit Sakakini)

institution-builder, an exceptional contributor to the profession, a major force advancing the role of women in academia, and a successful consultant, all while being married with two small children. Sylvia Nasar (1995), in the *New York Times* feature article she wrote about Susan when she was on the job market, quoted me (accurately) as calling Susan "Superwoman." At the time, both Susan and I were a little embarrassed by my seeming hyperbole. In the intervening dozen years, I have come to believe that I was not really exaggerating at all.

A Brief Biography

Susan was born in Boston and grew up in the Maryland suburbs of Washington, D.C. Her father is a physicist, and her mother taught English. Susan has one sister, who is 17 months older and a psychiatrist. Although Susan claims to have spent her early teenage years on sports and a very active social life, she did well enough in school to enter Duke University at age 16. She started out studying mathematics and computer science, was active in a sorority, and headed the field hockey team.

A recommendation from fellow student Leslie Marx (herself now a professor at Duke) led Susan to a research assistantship with Robert Marshall in Duke's economics department, Susan's first real involvement in economics. Susan had had a summer job preparing bids for a company selling personal computers to the government through procurement auctions, and she had noted that the low cost of disputing the outcomes of these auctions made for very frequent protests from losers. These protests often led to payoffs from the winners to the losers in legal settlements. Susan and Bob concluded that these payments might in fact be a mechanism to reward cooperatively high bids from the "losers." After Bob testified to Congress on this matter, the government eventually reformed its auction rules. The experience of seeing how "economic theory could change the world" made Susan sure she wanted a career in economics. She was "completely sold."

Her interest in auctions influenced her decision to attend the Stanford Business School's doctoral program rather than any of the top economics departments that had admitted her. At Stanford, she shone in the classroom while quickly getting involved in her own research. Her first research project, with fellow students Chris Avery and Peter Zemsky, eventually led to "Mentoring and Diversity" [1], while another, with Armin Schmutzler, yielded "Product and Process Flexibility in an Innovative Framework" [2], her first professional publication. Another organizational economics project, with fellow students Joshua Gans, Scott Schaefer, and Scott Stern, led to her developing methods of monotone comparative statics for situations of uncertainty (discussed further below). These methods were the heart of her dissertation, "Comparative Statics in Stochastic Problems with Applications," which Paul Milgrom and I co-chaired and which won her a great many job offers and a place on the European tour for outstanding graduating Ph.D.'s sponsored annually by the *Review of Economic Studies*.

Susan's first academic appointment was in the MIT economics department, where she held the Castle Krob Career Development chair. During her time at MIT she spent a year visiting Yale and another year as a National Fellow at the Hoover Institution. In 2001, Susan became engaged to Guido Imbens, then a professor at UCLA, and the two of them moved to the Bay Area, she to the Stanford economics department as a tenured associate professor and he to Berkeley. She also became a Research Associate of the National Bureau of Economic Research that same year, and she won the Elaine Bennett Research Award, given "every other year to recognize, support, and encourage outstanding contributions by young women in the economics profession" by the AEA's Committee on the Status of Women in the Economics Profession. In 2002, she and Guido were married. In 2004, she was promoted to full professor and awarded the Holbrook Working Professorship at Stanford, and she was elected a Fellow of the Econometric Society. She spent the 2004–2005 academic year at the Center for Advanced Studies in the Behavioral Sciences. In 2006, she and Guido both accepted offers from the Harvard economics department, where she is now a professor. They have two children, Carleton (born 2004) and Annalise (born 2006). Meanwhile, in her spare time, Susan is a member of the Executive Committee of the American Economic Association and of the

Council of the Econometric Society, and she is coeditor of the *American Economic Journal: Microeconomics*, one of the new AEA journals. In spring 2008, she was elected a fellow of the American Academy of Arts and Sciences.

In the remainder of this essay, I will attempt to explain the nature and significance of Susan's most prominent research contributions. Numerical references are to the papers listed in Table 1.

Monotone Comparative Statics under Uncertainty

Monotone comparative statics analysis involves establishing whether the solution to an economic model behaves monotonically in the parameters of the model. For example, does raising a tax rate decrease a consumer's purchases of some good, or does a change in the elasticity of demand increase oligopolistic equilibrium prices? Traditionally, there have been three approaches to doing comparative statics. In optimization problems, it has sometimes been possible to use revealed preference arguments, which rely solely on the particular structure of the problem and the necessary properties of the optima. Unfortunately, the set of problems that are amenable to this approach is limited. More often, methods based on applying the Implicit Function Theorem to the first-order necessary conditions for an optimum are used to obtain formulae for the derivatives of the optimal solution with respect to the parameters. A problem with this approach is that it typically involves imposing assumptions (such as differentiability and strict quasiconcavity) that are economically restrictive and whose relevance to monotonicity is obscure. In addition, one still has to impose whatever other economic assumptions are needed to sign the derivatives. The third approach involves making sufficiently strong assumptions on functional forms that the solution can be explicitly calculated for differing parameter values. This approach obviously leaves questions about the robustness of results to the specific assumptions.

Building on work in mathematical programming by Topkis (1978), Paul Milgrom and I (1990) introduced a fourth approach into economics. Like revealed preference, it relies solely on properties of the primitives of the model. Strikingly, the sufficient conditions to establish monotonicity of the model's solutions do not involve the sorts of assumptions needed to apply the Implicit Function Theorem, so indivisibilities, increasing returns, and the like are no problem. The key "supermodularity" property in our work—that the returns to increasing any choice variable should be nondecreasing in the parameters ("increasing differences" between each choice variable and the parameters) and that increasing any choice variable should not decrease the returns to increasing any other choice variable and should not prevent such an increase ("complementarity" among the choice variables)—are themselves monotonicity conditions on the objective function. In a

Table 1
Selected Papers by Susan C. Athey

1. "Mentoring and Diversity," (with Chris Avery and Peter Zemsky). 2000. *American Economic Review,* 90(4): 765–86.
2. "Product and Process Flexibility in an Innovative Environment," (with Armin Schmutzler). 1995. *RAND Journal of Economics,* 26(4): 557–74.
3. "Monotone Comparative Statics Under Uncertainty." 2002. *Quarterly Journal of Economics,* 118(1): 187–223.
4. "Characterizing Properties of Stochastic Objective Functions." 2000. MIT Working Paper 96-1R. http://kuznets.fas.harvard.edu/~athey/CSO0900.pdf.
5. "The Value of Information in Monotone Decision Problems" (with Jonathan Levin). 1998. MIT Working Paper 98-24. http://kuznets.fas.harvard.edu/~athey/VOI.pdf.
6. "Single Crossing Properties and the Existence of Pure Strategy Equilibria in Games of Incomplete Information." 2001. *Econometrica,* 69(4): 861–90.
7. "The Optimal Degree of Monetary Policy Discretion," (with Andrew Atkeson and Patrick Kehoe). 2005. *Econometrica,* 73(5): 1431–76.
8. "Collusion and Price Rigidity," (with Kyle Bagwell and Chris Sanchirico). 2004. *Review of Economic Studies,* 71(2): 317–49.
9. "Optimal Collusion with Private Information," (with Kyle Bagwell). 2001. *RAND Journal of Economics,* 32(3): 428–65.
10. "Collusion with Persistent Cost Shocks," (with Kyle Bagwell). 2008. *Econometrica,* 76(3): 493–540.
11. "Efficiency in Repeated Trade with Hidden Valuations," (with David Miller). 2007. *Theoretical Economics,* 2(3): 299–354.
12. "An Efficient Dynamic Mechanism," (with Ilya Segal). 2007. http://kuznets.fas.harvard.edu/~athey/EfficientDynamic.pdf.
13. "Designing Efficient Mechanisms for Dynamic Bilateral Trading Games," (with Ilya Segal). 2007. *American Economic Review (Papers and Proceedings),* 97(2): 131–36.
14. "Investment and Market Dominance," (with Armin Schmutzler). 2001. *RAND Journal of Economics,* 32(1): 1–26.
15. "An Empirical Framework for Testing Theories about Complementarities in Organizational Design," (with Scott Stern). 1998. NBER Working Paper 6600. http://kuznets.fas.harvard.edu/~athey/testcomp0498.pdf.
16. "Identification in Standard Auction Models," (with Philip Haile). 2002. *Econometrica,* 70(6): 2107–40.
17. "Empirical Models of Auctions," (with Philip Haile). 2007. In *Advances in Economics and Econometrics: Theory and Applications, Ninth World Congress, Volume II.* Ed. Richard Blundell, Whitney K. Newey, Torsten Persson, 1–45. Cambridge University Press.
18. "Nonparametric Approaches to Auctions," (with Philip Haile). 2007. *Handbook of Econometrics,* Volume 6A, ed. James J. Heckman and Edward E. Leamer, 3847–965. North-Holland.
19. "Identification and Inference in Nonlinear Difference-in-Difference Models," (with Guido Imbens). 2006. *Econometrica,* 74(2): 431–98.
20. "Discrete Choice Models with Multiple Unobserved Choice Characteristics," (with Guido Imbens). *International Economic Review,* 48(4):1159–92. November 2007.
21. "Information and Competition in U.S. Forest Service Timber Auctions," (with Jonathan Levin). 2001. *Journal of Political Economy,* 109(2): 357–415.
22. "Comparing Open and Sealed Bid Auctions: Theory and Evidence from Timber Auctions," (with Jonathan Levin and Enrique Seira). 2004. http://kuznets.fas.harvard.edu/~athey/comparingformats0904.pdf.
23. "Position Auctions with Consumer Search," (with Glenn Ellison). 2007. http://kuznets.fas.harvard.edu/~athey/position.pdf.
24. "Information Technology and Training in Emergency Call Centers," (with Scott Stern). 1999. In *Proceedings of the Fifty-First Annual Meetings* (New York, Jan 3–5, 1999), pp. 53–60. Madison, WI: Industrial Relations Research Association.
25. "Adoption and Impact of Advanced Technologies in Emergency Response Systems," (with Scott Stern). 2000. In *The Changing Hospital Industry: Comparing Not-for-Profit and For-Profit Institutions,* ed. David Cutler, 113–155. University of Chicago Press.
26. "Organizational Design: Decision Rights and Incentive Contracts," (with John Roberts). 2001. *American Economic Review Papers and Proceedings,* 91(2): 200–205.

differentiable context, they amount to the various cross partials being non-negative. It further turned out that these sufficient conditions are close to necessary, in that they have to hold if the monotonicity conclusion is to be robust to perturbations in the model.[1]

In the context of decisions involving uncertainty, monotonicity of the optimal choice of $\boldsymbol{x}$ in the parameter θ is then assured if the expected payoff $U(\boldsymbol{x}, \theta)$ has increasing differences in θ and the individual choice elements x_i and, for each i and $j \neq i$, x_i and x_j are complements. However, the actual primitives in such a model are the payoff $u(\boldsymbol{x}, \boldsymbol{s})$ to choice $\boldsymbol{x}$ in the state of nature $\boldsymbol{s}$, and the distribution of the uncertainty, given by the parameterized density $f(\boldsymbol{s}, \theta)$. For example, $\boldsymbol{x}$ might be an investment choice whose payoffs are random and variations in θ change the distribution of uncertainty, perhaps decreasing its variance. What conditions on these two u and f functions ensure that the solution $\boldsymbol{x}^*(\theta)$ is monotonic in θ?

Paul Milgrom reported that he had given some thought to this problem in the early 1990s, but believed it was just too hard to solve. Susan solved it in her dissertation, the central results of which are reported in [3]. It turned out later that a number of the results she obtained had been developed earlier in the statistics literature, but she conjectured and proved them on her own while moving well beyond the statisticians on dimensions crucial to economics.

A positive function is called log-supermodular if its log is supermodular. Log-supermodularity of the expected payoff $U(\boldsymbol{x}, \theta)$ is clearly sufficient for monotonicity of the optimal choice $\boldsymbol{x}^*(\theta)$, since applying a monotone increasing transformation to the objective does not affect the optimal solution as a function of the parameters. Log-supermodularity is convenient to use when looking at products of functions, as in decisions under uncertainty, and Susan's analysis focused on it. (She also looked at various "single-crossing" conditions.) Her first main result was that if the functions giving the payoff in any state of nature $u(\boldsymbol{x}, \boldsymbol{s})$ and the distribution of uncertainty $f(\boldsymbol{s}, \theta)$ are each log-supermodular, then the expected payoff function $U(\boldsymbol{x}, \theta)$ is also log-supermodular, which establishes that the solution to the decision problem will vary monotonically in the parameter.[2] She also

[1] Milgrom and Shannon (1994) obtained an actual necessary and sufficient condition for monotone comparative statics, but their condition is hard to check and thus to use. Indeed, I believe the first time it was used in other work was by Susan in [6], which I discuss shortly.

[2] Specifically, the solution of the optimization problem,

$$\arg\max_{\boldsymbol{x} \in B} \int u(\boldsymbol{x}, \boldsymbol{s}) f(\boldsymbol{s}, \theta)\, d\,\mu(\boldsymbol{s}),$$

is nondecreasing in both θ and the set B (where we define an appropriate order on sets, both for the constraint set and the set of optimizers).

explored the trade-off between imposing restrictions on the payoff functions and on the distribution of uncertainty, identifying "minimal pairs" of sufficient conditions for monotonicity—ones that cannot be relaxed on one dimension without demanding more on the other and still maintain the conclusion.

In [4], which also grew out of her dissertation, Susan explored conditions on the distributions of uncertainty $f(\boldsymbol{s}, \theta)$ that ensured that the expected payoff $U(\boldsymbol{x}, \theta)$ function is supermodular for all state-dependent payoff functions $u(\boldsymbol{x}, \boldsymbol{s})$ in a class of such functions that is closed under affine transformations and limits. Examples include increasing, convex, and supermodular u functions. It turned out that there are deep connections to the different concepts of stochastic dominance. Apparently, Susan uncovered the basic mathematical structure of these problems on Christmas Eve before heading off to the meetings where she was to be on the market.

With Jonathan Levin, Susan built on the insights obtained in [3] to explore the value of information in monotone decision problems, ones in which receiving a higher ("more optimistic") signal about the unknown state of the world induces the decisionmaker to take a higher action [5]. They cited as examples of such problems production under uncertainty about marginal cost or demand elasticity; financial or real investment; contracting; auctions; adverse selection; search; and coordination under uncertainty. They provided definitions of "more information" geared to different monotone decision problems such that every agent faced with such a problem will prefer one information structure to another if and only if the two are ranked according to the conditions. They also obtain results ranking different decisionmakers' demands for information.

In arguably the most important paper in this line of work, Susan used the techniques and concepts from her dissertation to examine the existence of pure strategy Nash equilibria in a significant class of games of incomplete information [6]. Earlier existence proofs for such games had invoked a variety of assumptions. Susan came up with one simple but sufficient condition: that if every other player was using a strategy that was a nondecreasing function of her (privately known) type, then a given player would have a best reply that was a nondecreasing function of her own type. This paper thereby provided existence results for a wide class of games, including first-price, multi-unit, and all-pay auctions; pricing games with incomplete information about costs; and noisy signaling games. For many of these, existence had not been established before. The paper is an absolute technical *tour de force*. Particularly notable are the extremely clever constructions Susan used, which reflected her deep insight into the mathematical structure of the problem, and her mustering of all the earlier literature. At the same time, her paper is full of rich examples to which Susan applied her methods. Beyond that, like all her work, it is eminently readable. This paper has spawned a literature building upon it in different ways by McAdams (2003, 2006), Reny and Zamir (2004), and Reny (2007).

Dynamic Games and Mechanisms

Susan has made major advances in studying repeated and dynamic games, and, in particular, ones where the players have private information about their payoffs (their "types") and these types may change stochastically over time. Some of this work has been geared to monetary policy models, where the monetary authority is privately informed about the state of the economy, but most has been in a context of implicit collusion, where firms are privately informed about their cost realizations. One further paper is about repeated dealings between a buyer and a seller, and some recent work takes a very general approach not geared to a particular application. Applications and extensions in other contexts by Hauser and Hopenhayn (2005) and by Abdulkadiroglu and Bagwell (2007) show the breadth of applicability of these methods.

It turns out that the fundamental questions in the problems Susan has addressed in this area can be framed as "rules and rigidity," where private information is ignored at the expense of efficiency today, versus "discretion and efficiency," where decisions do respond to private information while incentives are provided through current and future play, possibly creating inefficiency in the future as a result. The remarkable contribution of this work is to provide theoretical explanations for ideas and observations that have long been prominent in the literature though they are not derived from formal analyses.

Throughout this work, the approach is that of mechanism design; the idea is to find the best equilibrium for the players subject to the constraints imposed by incentives and budget balance. Methodologically, the key is to develop a recursive, dynamic programming formulation for the problem, an approach originated by Abreu, Pearce, and Stacchetti (1990) in their pioneering analysis of repeated games with imperfect observability of choices.

In [7], Susan, Andrew Atkeson, and Patrick Kehoe examined a version of the models of monetary policy due to Kydland and Prescott (1977) or Barro and Gordon (1983). Society seeks to maximize a social welfare function, and the monetary authority sets policy to achieve this maximization. Its private information about the state of the economy is valuable to this task, which argues for giving the authority discretion over policy. However, the authority has an incentive to behave in a time-inconsistent manner and pump money into the economy unexpectedly, inducing unexpected inflation, since this raises welfare in the short run if it is indeed unexpected. However, if private individuals understand this incentive and act in light of that knowledge, the results are undesirable. As a result, society may want to limit the discretion of the monetary authority.

Susan and her coauthors solved the dynamic optimal mechanism design problem that arises in determining just how much discretion to give and in which circumstances. Although one might have expected that the resulting rules would be quite complicated, in fact they are remarkably simple: There is a maximum inflation rate that the authority is allowed to induce, and it has discretion to set a lower rate. As the time-inconsistency problem becomes more severe, the amount of discretion allowed goes to zero. This rule is very close to the policy of inflation targeting that has been advocated by some policy-oriented monetary economists, including Federal Reserve Chairman Ben Bernanke.

Susan's work on collusion with private information about costs began in [8], collaborating with Kyle Bagwell and Chris Sanchirico. In a Bertrand game with inelastic demand, firms' cost levels in each period are private information (realizations of independent and identically distributed random variables). The efficient thing to do would be to have the lowest-cost firm supply the market in any period. If the firms could communicate with one another and could make side-payments, then they could arrange for the lowest-cost firm to get the entire market while charging its monopoly price (Cramton and Palfrey, 1990; Kihlstrom and Vives, 1992). However, if side-payments are not possible, this outcome cannot be achieved. Then there is a trade-off. On the one hand, there are efficiency gains if production can be allocated to the lowest-cost firm(s), which requires essentially having each firm report its costs honestly (that is, set prices that are strictly increasing in its cost). But providing incentives to report correctly involves distorting prices away from the monopoly level and may also involve price wars after very low cost realizations, both of which are costly.

Susan and her coauthors in [8] examined symmetric equilibria. At any point in time, such an equilibrium amounts to a function giving each firm's price as a function of its cost and an associated equilibrium continuation value of play for each realized vector of prices, where this value is symmetric across firms, so that firms experience cooperation and price wars symmetrically. They showed that if different cost levels lead to different prices (so that the lowest-cost firm gets to produce the market demand) then the firms can do no better than repeat the static Nash equilibrium, where all prices are bounded by the highest possible cost level, no matter how great is the reservation price. They then determine the optimal symmetric equilibrium. Most strikingly, under plausible conditions, the optimal equilibrium involves complete abandonment of the goal of efficient allocation of production (and thereby avoids the costs of information revelation). Instead, prices are completely rigid at the reservation price, with each firm getting $1/n$ of the market. Eighty years of empirical research had linked price rigidity with oligopolistic collusion. This appears to be the first fully developed theoretical explanation of the phenomenon.

In [9], Susan and Kyle Bagwell looked at a similar set-up without assuming symmetry, but with only two firms with two possible cost levels. Without symmetry, a firm can be induced to report high costs today by promises of a higher continuation value, achieved by allocating it a bigger market share in some future periods (ideally, when both firms have the same cost levels, so there is no efficiency issue in allocating production among them). A key result that contrasts with the results in [8] is that sufficiently patient firms can achieve first-best joint profits, with all the market-share rewards taking place when both firms experience the same cost level.

When the firms are not sufficiently patient to achieve first-best, they have to give up either monopoly pricing or efficient allocation of (current or future) production to prevent price-cutting. It turns out that the solution is typically to maintain prices and forego productive efficiency. Rather than cut prices, production is allowed to come from a high-cost firm when the other has low costs.

The analysis in [10] (with Kyle Bagwell) introduced persistence in the cost shocks. In this setting, the game is no longer a repeated one, but instead a dynamic game with privately known state variables. Firms now have new incentives to attempt to influence others' *future* beliefs about their costs. If the shocks are perfectly persistent, then the best the firms can do under plausible conditions is to share the market equally at the reservation price. (These conditions are similar to those for the parallel result in [8].) Meanwhile, if persistence is not too great relative to the patience of the firms, then first-best can be achieved by rewarding current announcements of high costs by larger future market shares in periods when both firms have the same costs, as in [9].

In a seminal contribution, Myerson and Satterthwaite (1983) studied trade in a single meeting between a buyer and a seller whose valuations for the good in question are identical and independently distributed random variables whose realizations are private information. They showed that efficient trade is impossible if we require that, knowing their own valuations, the players are willing to trade (individual rationality), that they will reveal their valuations honestly (incentive compatibility), and that in expectation the amount paid by one just equals the amount received by the other (budget balance). In recent work [11], Susan and David Miller have placed the problem in a repeated context to see whether repetition will permit a reversal of the negative Myerson–Satterthwaite conclusion. They accentuate the sensitivity of what can be achieved to the form that the individual rationality, incentive compatibility, and budget balance conditions take. In particular, it matters whether budget balance must be realized for every realization of the valuations, only in expectation, or in some intermediate way involving bounds on how big the surplus or deficit can be. It also matters whether the incentive compatibility and individual rationality constraints are as defined above, where they must hold in expectation over the other party's possible value but given each possible actual value of the party in question, or instead must hold for every possible value of both parties' valuations. The authors interpreted these differing specifications as reflecting different institutional contexts.

Finally, in a pair of papers [12, 13] Susan and Ilya Segal investigated a very general formulation of the dynamic mechanism design problem with private information. The formulation allows for contractible as well as private actions and complicated intertemporal interdependencies that permit both earlier signals and actions to affect the distribution of current signals. There are two key results, both of which concern the existence of transfers that implement efficiency—that is, transfers that provide incentives for truthful revelation when the decision plan specifies efficient allocation in each period. The first result is that there exist transfers, not budget balanced, that implement efficiency as an equilibrium that can be achieved, as long as an assumption of "private values" is satisfied. The second is that there exist budget-balanced transfers that implement efficiency as a Bayesian Nash equilibrium as long as values are private and information is independent across players. Susan and Ilya also consider conditions under which the transfers may be self-enforcing in a decentralized dynamic game among privately informed players. This work defines the frontiers of the field.

Outside the context of private information but still in the realm of dynamic games, in [14], Susan and Armin Schmutzler examined dynamic oligopoly games where firms may invest to improve future demand and/or costs, as in learning-by-doing, patent races, network externalities, or product and process innovations. Their concern was to understand the effect on firms' investment incentives of differences in their positions and to predict the dynamics of market structure. They identified conditions under which a firm with a lead will invest more than a laggard would and, further, conditions under which the leaders actually increase their market shares, extending their leads. The results rely on a new monotone comparative statics result applicable to games with strategic substitutes, ones where increasing one player's action reduces the marginal returns to opponents' choices. Their results apply to a remarkable range of oligopoly models from the literature.

Econometrics

Susan has undertaken a number of research projects in econometrics. The first [15] was with Scott Stern. They were concerned about testing for complementarity in organizational design problems. Traditional approaches to testing for complementarity are based on tests for positive correlation among the practices adopted or on estimating production functions involving interaction terms among the practices. Susan and Scott first examined how unobserved heterogeneity in the returns to adopting different organizational practices could bias the standard approaches. In particular, they showed that if the unobserved returns to adoption are affiliated (a strong form of positive correlation), then under simple conditions both the correlation test and the estimates from regression can be biased upward, so that both might suggest complementarity when none was there. Instead, affiliation means that the unobservable returns to adopting two practices both tend to be high together, driving the practices both to be adopted together, even though they are not complements. The authors then went on to develop a structural approach to identification and testing for complementarities and to offer suggestions about the sort of data that should be collected if one is planning to examine complementarity questions. This paper is still not published, but it has had a great impact: According to Google Scholar, it is Susan's most cited work.

Three papers that Susan has written with Philip Haile focus on econometric issues in auctions. Auctions are a very active subject of study, not only because they are of increasing actual importance in allocating goods but also because they are market mechanisms where we are well positioned to model preferences, institutions, and the induced behavior. Auction theory goes back to Vickrey (1961), while empirical work is more recent (and Susan has been a major contributor—as discussed below). Susan's work with Philip was among the pioneering efforts to develop the econometrics of auctions.

In [16], Susan and Philip presented results on the possibility of nonparametric identification of a large class of different auction designs. Nonparametric identification is very desirable, even if one does not plan to use nonparametric methods of estimation. It is important to know if, with the data at hand, we can determine which distribution of underlying random variables (for example, bidder values) and mapping to observables (for example, the auction rules and equilibrium bidding functions) actually generated the data, without making strong assumptions on the functional form of the underlying distribution, about which we typically have little information. Of course, identification depends crucially on what data is available, and this varies with the auction design. For example, in a sealed-bid auction, the econometrician might observe all the bids, but in an ascending or English auction, the highest bid that the winner would have made is not observed, while in a descending or Dutch auction, only the first bid can be observed. Susan and Philip show that, in the widely studied (both theoretically and empirically by parametric methods) case of independent private values (where knowing my value gives no information about yours), just knowing the transaction price is enough. In cases with affiliated or common values, however, this is not enough; even the English auction is unidentified without additional information. However, the authors show that the sort of ancillary data that is often available (bidder identities or bidder- or auction-specific covariates) may permit identification. Yet in the common values case (where everyone would ultimately value the good the same, but initially they only have private signals of that common value), results are few. This finding motivates the authors to study when one can establish empirically whether values are independent or common. In [17] and [18], they survey the field more broadly.

With Guido Imbens, Susan has also tackled the econometrics of the popular "differences in differences" methodology [19]. "Diffs in diffs" models seek to permit estimation of the effect of a "treatment" (like a change in the minimum wage or a health intervention) on some characteristic of a subject population when there are time-dependent changes going on in the relevant characteristic that confound identifying the treatment effect. The idea is to take two subgroups, one of which gets the treatment and the other does not, and compare the change across time in the characteristic of the untreated group with that of the control group, with the difference in the differences being used as the measure of the effect of the treatment. Susan and Guido offered a much more general model than had previously been used. It both dispensed with a variety of substantive assumptions that had been needed previously and, at the same time, permitted stronger conclusions.

Their approach relied on their deep insight into the fundamental structure of the problem.

More recently, Susan and Guido have studied identification in models of consumer choice among discrete alternatives [20]. Such models are widely used in industrial organization.

At one time, economic theorists (then called "mathematical economists") often contributed importantly to econometrics; that is why the Econometric Society is called what it is. Such people are rare today. Susan stands out among the few. Moreover, she has actually done serious empirical work, something that was not common even among the generation who did both theory and econometrics. Much of this work has concerned auctions.

Applied Auction Research

Auctions first brought Susan into economics, and she has contributed on all dimensions to research on the subject. Susan's theoretical work on collusion in repeated games applies to auctions, as does her existence theorem for games with private information, and (as just noted) she has done innovative work on the econometrics of auctions. To top it off, she has done significant empirical work in the area, as well as design work that has had major effects on business and public policy.

In [21], Susan and Jonathan Levin examined the U.S. Forest Service's (oral ascending) auctions for the rights to cut timber in the national forests. Typically a given tract contains several different species of timber-yielding trees. The Forest Service publishes an estimate of the proportions of the different species based on an inspection. Potential bidders then can conduct their own inspections. Bids are multidimensional: amounts to be paid per unit for each species. The winner is determined by aggregating each bidder's offer using the Forest Service's estimated proportions. The actual amount the winner pays, however, is computed by applying the bid vector to the actual amounts that are ultimately harvested (the winner has two years to complete the harvest).

These rules create an incentive for a bidder whose estimate of the proportions differs from that of the Forest Service to skew its bidding, raising the price bid for the species that the bidder believes are less common than does the Forest Service, and conversely lowering the price bid for the species that the bidder believes are more common than does the Forest Service. For example, suppose there are two species and the Forest Service estimates that they are in equal proportions, but a bidder believes they are in proportions 3:2. Then bids of ($100, $100) and ($50, $150) yield the same amount under the Forest Service proportions and so are equally likely to win, but the bidder's expected payment under the first is $100 and under the second it is $90.

Susan and Jon first modeled and solved for equilibrium bidding behavior in this sort of auction. Then, using data on the bids plus the actual harvests, they found evidence that suggests that the bidders do indeed have private information about the species proportions and that they are using it in the subtle ways predicted by the theory.

With Enrique Seira, Susan and Jon have compared the performance of sealed-bid first-price and ascending oral auctions empirically, again using Forest Service data [22]. The celebrated Revenue Equivalence Theorem suggests that, under certain conditions, a great variety of auction designs yield the same winners and the same revenues. So a first step the authors took was to enrich the basic theory to allow for bidder heterogeneity (some bidders are mills that can process the logs themselves; others are loggers who must sell the logs they harvest). This heterogeneity creates differences in theoretical performance between the auctions, especially once bidder entry is endogenized by introducing costs of becoming informed and of bidding. For example, weak bidders are more likely to participate in sealed-bid auctions because they have a better chance to win as a result of the strong bidders' greater incentive to shade their bids from their actual values.

Susan and her coauthors established empirically that when comparing the two auction designs, the effect of the auction format on participation is much larger than its effect on bidding, conditional on participation—that is, how many bidders enter is more important than how they bid once they get there. In addition, using bidding behavior from first-price auctions as a benchmark, the authors provided evidence that suggests some measure of collusion in the ascending auctions but competitive behavior in the sealed-bid auctions. Theory suggests that ascending auctions should be more subject to collusion. This work is unusual because it is rare that the data will permit comparison of different auction designs. Here both designs were used by the Forest Service in an apparently random way, allowing comparison.

More recently, Susan has turned her attention the problem of search advertising auctions, where the objects being auctioned are positions in an ordered list of sponsored links. Together with Glenn Ellison [23], she developed a theoretical model of firms bidding in these auctions, where consumers' decisions to click on sponsored links are endogenous and consumers face search costs. Advertisers differ in the probability that they can meet the need of a consumer who entered a particular search phrase. They used the model to address a number of issues about the design of these auctions, such as reserve price policy. In standard auction settings where the value of winning is exogenous, reserve prices increase auctioneer revenue but decrease social welfare, since the reserve price eliminates some efficient transactions between the auctioneer and the bidders. Susan and Glenn showed that in the sponsored link auction with endogenous consumer search, reserve prices increase social welfare by eliminating the poorest-quality advertisers and raising the average quality of the remaining advertisers, thereby inducing more search by rational consumers in equilibrium. Based on this research, Susan has advised Microsoft Corporation on the design of their sponsored search auctions.

On the public policy front, Susan worked with the government of British Columbia to reform the way it allocated rights to harvest timber, introducing an auction in place of the simple stumpage fees that had been used. The allegedly inappropriately low levels of these fees had been the basis for antidumping rulings sought by the U.S. softwood industry. These in turn were a major element in a rancorous international dispute between the U.S. and Canada. As well, Susan advised the government of Victoria, Australia, in establishing a combinatorial auction for timber.

Organizational Economics

Finally, Susan has made an eclectic set of contributions to the economics of organizations. Her work on the econometrics of complementarities in organization design [15] was discussed above. She has also contributed theoretical models of organizational issues and empirical investigations.

In her first published paper [2], Susan and Armin Schmutzler examined a two-period model of the firm in which the firm first makes long-run organizational decisions that affect the costs and benefits of adopting future innovations. In particular, first-period investments in research capabilities determine the distributions of returns to future cost-reducing process innovations and demand-enhancing product innovations, while investments in product and process flexibility determine how costly it will be to adopt each sort of innovation. Given the choices on these four dimensions, in the second period the firm realizes opportunities to adjust its current products and processes and must decide whether to adopt either or both of these. It must also select the quantity of output. Under natural and plausible assumptions, the adoption decisions are complementary: adopting either innovation makes adopting the other more profitable. This choice in turn can induce complementarity among the long-run organizational choices, so that increasing the investment in any one of them increases the returns to increasing all the others. Thus firms should be expected to cluster, being either very flexible on both products and processes and developing strong capabilities in both product and process innovation, or they should be relatively inflexible and un-innovative on both dimensions. This result was unexpected, at least judging from the management literature on operations and the management of innovation, which tended to argue for focus on either product or process innovation.

With Christopher Avery and Peter Zemsky, in [1] Susan took up the issues of diversity in organizations and bias in promotions. In their model, a firm has senior and junior employees. Each employee is of one of two types (which can be interpreted in terms of ethnicity, gender, or other categories). Junior employees also differ in their ability. Their productivity as seniors depends on their ability as augmented by mentoring from the seniors. Crucially, an employee of a given type gets more and better mentoring (and thus is more productive) the higher the fraction of seniors of her type. That means that if one type, say A, is overrepresented among the seniors, then juniors of that type will tend to be more productive.

Each period a fraction r of seniors of both types retire, and the firm has to decide which juniors to promote to replace them (this choice determines the profit for that period). Promoting the most productive employees, independent of type, is called "unbiased." Any other promotion policy is biased. The reason the firm might choose a biased policy is to change the proportion of each type at the senior level and thereby to change the efficacy of mentoring and thus make better use of the talent at the junior level. For example, bias in favor of the minority means more minority seniors in the future and a better ability to get value from minority juniors.

Chris, Susan, and Peter solved the dynamic optimization problem faced by the firm, examining the (complex) dynamics of this model and its steady states, which may be multiple. Biases in favor of the majority and of the minority are both consistent with equilibrium, even for a given firm at different points in time. Both complete homogeneity and complete mixing may be steady states, and it is also possible that a "glass ceiling" exists, with the minority never getting above a certain fraction of the senior population even though they are half the juniors. With the multiple steady states, an externally imposed constraint on the promotion policy may shift the firm to a new steady state, thereby giving a role for such policies (if society favors one state over the other).

In a pair of empirical papers with Scott Stern [24, 25], Susan investigated the effect of technology adoptions and human resource management practices in a service organization—the 911 emergency telephone system. Emergency call centers come in two forms. In the basic 911 version, a person in trouble calls 911 and the call-taker asks about the nature of the emergency and the caller's location, then sends the appropriate emergency personnel. In Enhanced 911, a program automatically determines the caller's location from the number of the telephone line on which the call has been placed. In [24], Susan and Scott found that adoption of Enhanced 911 paired with a job redesign for the call-takers significantly improved response time of ambulances called for heart attack victims and the ultimate survival rate from heart attacks. In [25], they added human resource policies—hiring and screening requirements, general employer-provided training and a specific training program that teaches how to gather and use information about medical emergencies. They found that adoption of Enhanced 911 technology interacted positively with both sorts of training, but not with selection variables. This work is appealing since it is a rare instance where the effects of information technology in a service setting can be cleanly identified.

Finally, Susan and I have a short paper than begins to explore the interplay between incentives and coordination in organizations [26]. We examined a situation where two agents must each take an unobservable effort choice and also select an investment that may have spillovers onto the other agent. The complication is that there is only a single performance measure for each agent, and it confounds the agent's effort choice, the investment choice, and the spillover from the other agent's investment. If the effort choice is unimportant, the optimal contract would pay both agents on the total return, so that the externalities are internalized and coordination achieved. On the other hand, if the investments are unimportant, the optimum is to pay on own performance and, if the noise in the two performance measures is positively correlated, negatively on the other's performance. We begin to examine the optimal solution when the allocation of decision rights over the investment is made a design variable in addition to performance contracts. One result is that hierarchy may be optimal, with either one of the agents being given authority, or a third party placed over the two. I hope we will return to work out fully the solution of this problem.

Conclusion

This review has suggested the immense breadth of Susan Athey's interests and, I hope, given some insight into the power of her intellect and importance of her contributions. It has not, however, even hinted at what a superb colleague, coauthor, teacher, mentor, and friend she is. Those characteristics were not criteria for the award of the John Bates Clark medal, but they are central to understanding why Susan is held in such high regard.

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