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What the FCC auctions can tell us about the performativity thesis

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Michel Callon's performativity thesis has attracted a great deal of attention within the science studies and economic sociology communities. Donald MacKenzie has called it "the most challenging recent theoretical contribution to economic sociology" (MacKenzie and Millo, 2003:107), Richard Swedberg has characterized this work as "important" for economic sociology (Swedberg 2004), and Patrick Aspers has observed that it has been "embraced, used and admired, and today ... is in vogue" (Aspers 2005). Rather than engaging economic performativity at a purely methodological level, I examine how the thesis is actually used today. In particular, I subject the case identified by Callon and MacKenzie as one of their exemplary empirical instances of "performativity" – the American institution of a certain specific type of auction to allocate communications spectrum licenses under the auspices of the US Federal Communications Commission – to a skeptical audit. Game theory, writes MacKenzie, "was no longer an external description of the auction, but had become – as Callon would have predicted – a constitutive, performative part of the process" (2002:22). I will argue that the evidence does not support the widespread impression, apparently shared by both the economics and science studies communities (Guala 2001; MacKenzie 2002; Parkin 1998), that economists' game theoretic accounts of auction theory dictated the format of the auctions adopted, and therefore rendered the economists' theories 'true' by construction.

Background

In 1994 the US Federal Communications Commission (FCC) commenced for the first time the practice of auctioning spectrum licenses to the highest bidder. The process of determining the best method of selling off rights to control certain frequencies of the electromagnetic spectrum was marked by another innovation: the heavy involvement of academic game theorists, practitioners of

one of the most abstract mathematical fields of economics, often thought to exist at a remove from practical problems. Once the first set of auctions were complete, and the dollar tally came in, those economists gleefully took credit for what was initially perceived as a highly successful performance. Within economics the episode has become the textbook exemplar of the practical relevance of game theory, and was directly responsible for the choice of at least one Nobel Prize recipient. Ten years after the close of the first round of auctions, fascination with the incident continues unabated, as evidenced by the attention given it by the science studies community.

Performativity's "research and development" account

In depicting the FCC auctions as the outcome of an instance of performativity, Callon and MacKenzie follow the work of Francesco Guala, who has developed an account of the FCC auctions as "a tour de force from [the] preliminary identification of the target to the final product" (2001:455). The US Congress established the "target", which was an auction that would meet several organizational, distributional, and macroeconomic goals. The "final product" was, in Guala's terminology, an "economic machine" which was representative of "our best science and technology"; he ultimately judged it to have been a "success" (2001:474–475). The "economic machine" account works by focusing on a stylized notion of techniques used in product research and development,¹ and derives its evidence almost exclusively from a few published accounts of the major game theory participants. From this vantage point, an R&D process takes place not only in the "abstract realm of theory", but also in the "university lab" (475), the different locations corresponding to different stages in the systematic process of developing a fully functioning "machine". Similarly, the performativity narrative is concerned with the construction of "calculated collective devices", and with the methods economists use to construct a "relationship between a market simulation in a laboratory and the actual 'scale one' market" (Callon and Muniesa 2003:9). The performativity narrative regards itself as following the econo-

mists around as they overcome difficulties and obstacles in the development process, some involving the “multiple constraints imposed by the FCC”, and others arising from the “nature of the goods” themselves (Callon forthcoming).² It is worth noting that neither Guala nor Callon have actually followed any economists around in this instance; what they followed instead is a subset of the economists’ own self-serving accounts published after the fact, or as related in interviews.³

While Callon stresses the inability of economic theorists to provide a “turnkey solution”, “the increasing role of experimentation in market engineering”, and the need for participants to “adopt a logic of compromise” (forthcoming), the economists who participated in the FCC auctions were quite prepared to admit that “the theory does not specify an unambiguous best form for the spectrum auction” (McMillan 1994:151), that experimental economists participated in the construction of an operational auction (Kwerel 2004; McMillan 1994), and that the final outcome represented a successful collaboration between several participant groups (Kwerel and Rosston 2000:261). Furthermore, they – like Callon – identified the characteristics of the spectrum commodity and the establishment by the government of “multiple aims” for the auctions as the primary reasons for abandoning the use of formal methods (McMillan 1994; also see McMillan et al 1997). Therefore, the most striking aspect of the performativity account is how little it adds to the firsthand accounts given by the participating economists.

Both the firsthand accounts provided by the economists and the performativity account tend to obscure the process of determination of the goals, the methods by which the economists were recruited by interested parties, and the *social* maneuvers used to deal with the presence of incompatible aims. As Callon (forthcoming) puts it, “It is not the environment that decides and selects the statements that will survive; it is the statements that determine the environments required for survival.” But in this particular instance an awareness of the different objectives pursued by the distinct participants is indispensable to understanding how the FCC auctions finally materialized.

The FCC auctions: a suggested reading⁴

It is commonplace for accounts of the FCC auctions to begin with a discussion of the stipulation of several goals for the auctions by the US Congress. This is a particularly

important feature of the performativity narrative, because it gives the impression that the goals for the auctions were propounded independent of the process, before it began. In fact, Congress charged the FCC with several goals pertaining to industrial organization, macroeconomics, and distributional equity. The FCC, however, would eventually take the position that all these complicated considerations should ultimately be reduced to the narrower “economic efficiency”, and that the most appropriate goal to pursue should be to award licenses to their highest valued users (FCC 1993:34; 1994:70).

By replacing the goals of Congress with their preferred “efficiency” criterion, the FCC staff economists were able to ground their policy analysis in game theory, the true significance of which was not, as has been commonly asserted, the substitution of political with scientific considerations (McMillan 1994; Milgrom 2004), but rather the enrollment of a specific group of academic game theorists into the FCC’s policymaking process. Academic game theorists were first invited to participate following the FCC’s release of a *Notice of Proposed Rulemaking* (NPRM) for Personal Communications Services licensing. In every rulemaking process, the FCC is required to ask for comments from “interested parties” – broadcasters, telephone companies, equipment manufacturers, industry groups, government agencies, and to a far less extent consumer groups – that would be affected by changes in administrative rules. This particular set of rule changes would be met with heated debate, as Congress punted the most contentious political issues to the FCC (Galambos and Abrahamson 2002:163–164). In response, FCC Chairman Reed Hundt hit upon the idea of calling for the involvement of game theorists. The appearance in the NPRM of a call for game theoretic analysis of auction policy was unprecedented, and gave certain interested parties the idea of hiring academic game theorists to further their objectives.

Those hoping to ground controversial public policy in uncontroversial science would soon be disappointed, as the enlistment of an increasing number of game theorists resulted in a remarkably diverse array of inconsistent recommendations concerning auction specifications, and ultimately a failure to produce any clear cut recommendation. One plan for the auction of licenses called for a sequence of English auctions (Weber 1993a; 1993b), a second called for a sequence of Japanese auctions (Nalebuff and Bulow 1993a; 1993b), and a third called for simultaneous sales of all licenses (McAfee 1993a; 1993b; Milgrom and Wilson 1993a; 1993b).⁵ Some proposals insisted

on admitting combinatorial bids for bundles of geographically linked licenses while others favored restricting bids to individual licenses only. The sticking point was that game theory supplied no global discipline with regard to the type of recommendations tendered: a game theorist could legitimately support any of an array of auction forms by stressing one set of information properties over others. Participants in the run-up to the spectrum auctions have acknowledged that game theory was unable to provide a knock-down argument for the optimality of a specific auction form (McAfee and McMillan 1996:171; McMillan, Rothschild, and Wilson 1997:429). A performativity account might attribute the lack of a determinate recommendation to the essential inadequacy of “abstract theoretical reflection” for the development of a working product, but faulting arid abstraction does not begin to get to the heart of the matter. The lack of a determinate recommendation was less a disagreement over the significance of various learning effects than it was a disagreement over the *aims* for the auction. While there was ample room for disagreement over the efficiency properties of the auction proposals, it is clear that firms’ narrowly constituted interests played a major role in the policymaking process:

[T]he business world was fully aware of [the strategic significance of] the rulemaking process and had engaged many groups of consultants to help position themselves. Businesses understood that the rules and form of the auction could influence who acquired what and how much was paid. The rules of the auction could be used to provide advantages to themselves or their competitors. Thus a mixture of self-interest and fear motivated many different and competing architectures for the auctions as different businesses promoted different rules (Plott 1997:606).

The most prominent “consultants” used by businesses to “position themselves” were the academic game theorists. Several firms responded to the FCC’s NPRM by lobbying for preferred sets of auction rules, and some – mostly Baby Bells and their progeny – enlisted academic economists to draft supporting comments: Nynex hired Robert Harris and Michael Katz of California-Berkeley; Telephone and Data Systems⁶ (TDS) hired Robert Weber of Northwestern; Bell Atlantic hired the Yale economist Barry Nalebuff and Jeremy Bulow of Stanford; Airtouch⁷ hired R. Preston McAfee from the University of Texas; Pacific Bell hired Paul Milgrom and Robert Wilson from Stanford. In accepting their role as consultants, the economists participated at the convenience of their clients:

... [Pacific Bell Attorney James] Tuthill, who organized Pac-Bell’s lobbying before the FCC, knew it would be crucial to hire an expert who could figure out where, amid the highly technical details of the auction proposal, PacBell’s interests lay ... He wanted someone who could speak plain English and come across to the FCC as more than just an opinion-for-hire. “If it’s just another party coming up and telling our line, that isn’t going to be effective” ... During the summer before the FCC released its auction plan, Tuthill’s staff drew up a list of games [sic] theorists ... By the time the FCC’s plan was in the hands of PacBell’s competitors, the company had signed a contract with Milgrom and Wilson. Although Wilson was a more senior professor, Milgrom was assigned the lead role because he was willing to lobby (Thelen 1995).

The requirements that economists would have to figure out where their clients’ “interests lay” and be “willing to lobby” deepened the controversy over the auction form, while decoupling proposals from the pursuit of anything resembling the public interest. The absence of a global theory of auctions (and the internal difficulties of the Bayes-Nash approach) provided opportunity for disagreement, but the high-stakes setting within which the design process took – along with the establishment of consultant relationships with most of the theorists – virtually ensured it.

The clearest example of businesses using economists to promote different auction architectures is provided by the assortment of comments pertaining to the use of a combinatorial auction.⁸ While all participants were in agreement that a combinatorial auction would ease the aggregation of licenses, detractors characterized this easing as “biased” while supporters characterized it as “efficient.” One economist – a consultant for Pacific Bell was remarkably candid about the relationship between corporate strategies and the proposals made:

In the US telecommunications spectrum auctions, sophisticated bidders anticipated the effects of packaging on the auction and lobbied the spectrum regulator [the FCC] for packages that served their individual interests. For example, the long distance company MCI lobbied for a nationwide license which, it claimed, would enable cell phone companies to offer seamless coverage across the entire country. MCI knew that if such a nationwide license plan were adopted, it would exclude existing mobile telephone service providers from bidding, because those providers were ineligible to acquire new licenses covering areas that they already served. In the same proceeding, regional telephone companies such as Pacific Bell lobbied

for licenses covering regional areas that fit well with their own business plans but poorly with the plans of MCI (Ausubel and Milgrom 2005:2).

Firms seeking nationwide coverage – not only MCI, but also Bell Atlantic and Nynex (Andrews 1994; Galambos and Abrahamson 2002; Skrzycki 1993) – supported nationwide package bidding, while firms pursuing regional strategies – Pacific Bell and Airtouch (Galambos and Abrahamson 2002; Kwerel and Rosston 2000:262; Thelen 1995) – supported licenses covering regional areas, and opposed package bidding. In between the two groups stood TDS, which favored package bidding, but only for regional groupings across license bands and not for a nationwide license. TDS was pursuing a regional strategy and had no intention to seek a nationwide collection of licenses (Murray 2002:270; Weber 1997:534).

In an ironic twist, the task of determining the public version of what academic game theory ultimately dictated fell to the FCC. Though the multiplicity of aims and proposals forced the FCC to display some creativity in conjuring a “consensus” recommendation for the auction form – the simultaneous-multiple round-independent auction [SMRI] – the SMRI auction did possess the virtue of being broadly consistent with the concerns of a distinct group of large telecoms who were united by their fear of being leapfrogged by MCI, which would assume a commanding position if it acquired a nationwide license.⁹

Working out the details of the never before implemented SMRI turned out to require more elaborate competencies and redoubled efforts beyond those deployed in the initial rounds of the public policymaking process. Consequently, experimental economists were recruited to participate in the design of the auction. Though the performativity account fosters the impression that it was the pesky abstractness of theory that prompted the inclusion of experimental economists, it was actually the adoption of a seemingly innocuous proposal of some game theorists to computerize the auction that unwittingly endowed experimentalists with their most important role. Attempts to produce a prototype auction failed.¹⁰ The FCC was thereby induced to seek help from the only economists who had actually produced a computerized auction, and it devolved to the experimentalists to accept major responsibility for coding the auction. Experimentalists did not view themselves primarily as software engineers or troubleshooters or *bricoleurs*, but rather as a distinct professional group in possession of their own ideas about how to design mar-

kets.¹¹ For our present purposes, it is possible to reduce the differences between game theorists and experimentalists to three primary areas of disagreement:¹²

1. While game theorists tended to represent markets as Bayes-Nash games, experimentalists represent them as combinatorial optimization procedures. Experimentalist market theory has roots in Walrasian general equilibrium theory, and particularly in efforts searching for determinate, Pareto optimal, price adjustment processes. They were particularly concerned with the existence of a competitive equilibrium in the presence of complementarities, and noted that complementarity produces a nonconvexity in the consumption set, which, if serious enough, rules out the existence of a competitive equilibrium (Banks et al 1989:2–3). In the absence of a competitive equilibrium prices no longer suffice to coordinate agents to optimal allocations (Ledyard et al 1997:656). The attainment of competitive equilibrium is generally not a concern for game theorists.¹³ What absorbs their attention, rather, is the putative mendacity of participants, who are the ultimate sources of information about the economy. For game theorists all the action happens in the mind of the participant, modeled as an inductive machine assumed to “learn” through Bayesian inference, while for experimentalists most of the action happens in the price adjustment process, conceived as a price discovery device.
2. Game theorists want to improve the “price system” by increasing the amount of information it provides, while experimentalists seek improvements in its capacity for information processing. Game theorists focus on methods for discovering and publicizing the information that they assume to be already dispersed in the minds of participants. While experimentalists are undeniably interested in the same information, they focus their efforts mostly on finding procedures – or “smart markets” – that will make best use of this increased access to information. This focus on construction of a tractable optimization program (a difficulty for integer-programming problems because they are computationally burdensome) encourages experimentalists to treat the market rules as an algorithm. There is no such equivalent imperative for game theorists, who provide only the most stylized descriptions of markets; they conceive of their machines abiding inside of peoples’ heads. While experimentalists tend to black box the mind to study features of the exchange

process, game theorists black box the exchange process to focus on treating the mind as an inference engine.¹⁴ As a consequence, it has been the experimentalists who have tended to foster appreciation of the importance of the sheer diversity of market forms.¹⁵

3. While game theorists generally judge the success of a market in how it assists learning, experimentalists tend to judge it by the reliability of the successful execution of trades. This is reflected in the different criteria used by the two groups. Game theorists pursue the criterion of ex post Pareto optimality (The bidder who would create the most value from owning the license wins it); experimentalists pursue ex ante Pareto optimality (The bidder who values the license the highest at the outset acquires it). These differences in criteria are responsible for different styles of arriving at a "solution": The experimentalists' prescription is frequently described as the product of a balancing act between "full central processing" of information, which relies on the processing algorithm to use the information, and "decentralization", which relies more on participants to use information. Because game theorists are only concerned with the "processing" that takes place in the heads of the participants they are concerned only with producing a form that maximizes the amount of information given to the participants.

Though experimentalists advocated for adoption of "smart markets", they ultimately failed to convince the FCC. They were limited by the client group they were engaged by – the NTIA (the US federal agency responsible for managing government spectrum usage). But when charged with the computerization of the auction, they took over responsibility for determining what criteria the market algorithms would meet. This work looked very much like the "bugchecking" that characterizes the manufacture of all computer programs – a practical activity directed at the development of an operational product – but actually freighted in a theoretical element as well. Banished were concerns with issues of learning, and the criterion of ex post Pareto optimality came to be trumped by 'technical' issues of computation and practical imposition of coordination and the criterion of ex ante Pareto optimality. But while the participation of experimentalists would significantly diminish game theorists' effective participation in the process of 'putting flesh on the markets', the experimentalists actually promoted the success claims of game theorists by encountering and resolving nagging

inconsistencies and ambiguities of the SMRI (Ledyard et al 1994; Plott 1997).

Conclusion

To review, the performativity narrative informs us that the FCC sets the goals for the economists to attempt to achieve, subject to Congressional constraints. My narrative finds fault with such an account for its portrayal of the economists, telecoms, and government officials as a single undifferentiated team united in pursuit of the pragmatic operability of a "machine". The FCC thought the economists might help them exert some control over the process of the allocation of spectra, but maybe they were a bit naïve. Game theorists and experimentalists were not necessarily 'on the same page', seeking to bridge the inevitable gap between pure science and its applied contexts. Everyone was busily trying to recruit everyone else, although some 'actants' – viz., the telecoms – were unequivocally 'more equal' than everyone else. Once the diversity of aims and understandings has been accounted for, we are left with a story in which some economists managed to redefine the goals for the government to achieve, subject to the telecoms' veto, while letting a different set of economists bask in the limelight and take the credit.¹⁶

The auctions as they finally materialized were a curious amalgam of technical achievement and crude politics, but the flat ontology of 'actants' and networks has only served to obscure the actual causes of events – most notably, the pivotal role of the telecoms in orchestrating the outcome. While space considerations have prevented reaching a final verdict on the performativity thesis here, clearly what is needed is a treatment of this thesis that stresses the connection of economic performativity to the research program of actor network theory, and would then show how performativity's R&D account is a logical outgrowth of that program. Finally, it would relate the shortcomings of its account of the FCC auctions to a broader discussion of the consequences of adopting its precepts for the larger project of science and technology studies. I would argue (Mirowski and Nik-Khah, forthcoming) that the enthusiasm for the doctrine of performativity is fostering a situation where science studies will come to increasingly resemble neoclassical economics, if not serve as its cheerleader.

Endnotes

1 For instance, Guala conflates the way a Walrasian theorist uses the terminology of 'mechanisms' with the way it is used by philosophers of science such as Nancy Cartwright and John Dupré. The terminological conflation is not harmless. A better history of postwar mechanism design in economics can be found in Lee (2004) and in Nik-Khah (2005).

2 The citations of Callon (forthcoming) refer to a draft version of a paper that might be subject to revision, and is scheduled to appear in a forthcoming book.

3 It should be mentioned that Guala appears to have different aims than Callon. Guala believes that "interpretations of a scientific theory (in the natural and the social sciences) should take applied science as their point of departure" (Guala 2001:453), and there uses that method to provide a philosophically motivated intervention to the debate over rational choice theory. His argument is that rational choice theory can be made to work with an understanding of its "real capacities."

4 Many aspects of this sequence of events will be related here in only the most cursory manner. However, they are covered in detail in Nik-Khah (2005).

5 An English auction is one for which prices increase, with the bidder placing the highest bid winning the item. A Japanese auction is similar to an English auction, but all participants are considered active bidders until they drop out. Studies of the formal properties of ascending auctions frequently substitute the Japanese auction for the English auction.

6 TDS is a member of the American Personal Telecommunications family of cellular providers that today goes under the marketing name of US Cellular.

7 At the time of the proposal, Airtouch was a wholly owned subsidiary of Pacific Bell with plans to spin off prior to the auctions.

8 The combinatorial auction is not the only example of using economic expertise to 'lobby the spectrum regulator', merely the most celebrated. Nearly every conceivable aspect of the auction proposals – from sequencing the sales to the release of bidder identities – conformed to the interests of the client telecoms.

9 MCI's decision not to participate in the auction was the direct result of the successful persuasion by game theorists of the FCC to reject nationwide combinatorial bidding (Thelen 1995).

10 The extent of this failure is on vivid display in the experimentalists' report to the FCC of their tests of the auction software (Ledyard, Plott, and Porter 1994).

11 There is a relationship between this observation, and the point made by Galison (1997) that experimentalists as a group have conceptual traditions themselves not determined by the beliefs of theorists. The route of the experimentalists to market

design through Walrasian mechanism design (and not game theory) is discussed by Lee (2004).

12 The full contrast is provided in Nik-Khah (2005).

13 There has been considerable misunderstanding of this point. For example, Guala tends to conflate Nash game theory with Walrasian general equilibrium theory: "Complementarities are one of economists' nightmares, because models of competitive markets with goods of this kind in general do not have a unique equilibrium and are unstable. No theorem in auction theory will tell you what kind of institution will achieve an efficient outcome" (2001:458). The ramifications of complementarity for uniqueness and stability have no place in auction theory, only in general equilibrium theory. However, one should admit that textbooks often elide this distinction to foster the impression of the unity of microeconomics.

14 Game theorists displayed no appreciation of the computational features of the market. The ways in which experimentalists tend to neutralize the vagaries of the minds of their subjects is discussed in Mirowski and Lee (2003).

15 This case is made with greater specificity in Mirowski (forthcoming).

16 This begs the question about the basis for presuming the auctions were, in fact, successful. I argue elsewhere (Nik-Khah 2005) that the auctions actually failed to meet both the goals established by Congress and those mooted by the participating game theorists.

References

- Andrews, E. (1994). "2 Phone Concerns Seeing to Merge Wireless Services." *New York Times*. June 29, 1994: A1.
- Aspers, P. (2005). "Performativity, Neoclassical Theory, and Economic Sociology." *Economic Sociology: European Economic Newsletter* 6(2): 33–39.
- Ausubel, L. and P. Milgrom (2005). "Ascending Proxy Auctions." *UCLA Department of Economics Working Paper*.
- Banks, J., J. Ledyard, and D. Porter (1989). "Allocating Uncertain and Unresponsive Resources: An Experimental Approach." *RAND Journal of Economics* 20(1):1–25.
- Callon, M. (forthcoming). "What Does it Mean to Say that Economics Is Performative?" In F. Muniesa, L. Siu, D. MacKenzie, eds. *Performing Economics*.
- Callon, M. and F. Muniesa (2003). "Les marches économiques comme dispositifs collectifs de calcul." *Resaux* 21(122): 189–233. [Translated version available: <http://www.coi.columbia.edu/pdf/callon-muniesa.pdf>].
- FCC (Federal Communications Commission) (1993). *Notice of Proposed Rulemaking* (NPRM). FCC Docket No. 93–455.

- FCC (Federal Communications Commission)** (1994). *Second Report and Order*. FCC Docket No. 94–61.
- Galambos, L. and E. Abrahamson** (2002). *Anytime, Anywhere: Entrepreneurship and the Creation of a Wireless World*. New York: Cambridge University Press.
- Galison, P.** (1997). *Image and Logic*. Chicago: University of Chicago Press.
- Guala, F.** (2001). "Building Economic Machines: The FCC Auctions." *Studies in the History and Philosophy of Science* 32(3):453–477.
- Kwerel, E.** (2004). "Forward." In P. Milgrom, *Putting Auction Theory to Work*. New York: Cambridge University Press.
- Kwerel, E. and G. Rosston** (2000). "An Insiders' View of the FCC Spectrum Auctions." *Journal of Regulatory Economics* 17(3): 253–289.
- Ledyard, J., D. Porter, and A. Rangel** (1997). "Experiments Testing Multiobject Allocation Mechanisms." *Journal of Economics and Management Strategy* 6(3):639–675.
- Ledyard, J., C. Plott, and D. Porter** (1994). "A Report to the Federal Communications Commission and to Tradewinds International, Inc.: Experimental Tests of Auction Software, Supporting Systems and Organization." PP Docket No. 94–12.
- Lee, K.** (2004). "Laboratory Markets as Information Systems: Vernon Smith Designs Some Mechanisms." Paper presented to HES conference, Toronto.
- MacKenzie, D.** (2002). "The Imagined Market." *London Review of Books* 24(21): 22–24.
- MacKenzie, D. and Y. Millo** (2003). "Constructing a Market, Performing Theory: The Historical Sociology of a Financial Derivatives Exchange." *American Journal of Sociology* 109(1): 107–145.
- McAfee, R.** (1993a). "Auction Design for Personal Communications Services." *Comments of PacTel* PP Docket No. 93–253.
- McAfee, R.** (1993b). "Auction Design for Personal Communications Services: Reply Comments." *PacTel Reply Comments* PP Docket No. 93–253.
- McAfee, R. and J. McMillan** (1996). "Analyzing the Airwaves Auction." *Journal of Economic Perspectives* 10(1): 159–175.
- McMillan, J.** (1994). "Selling Spectrum Rights." *Journal of Economic Perspectives* 8(3): 145–162.
- McMillan, J., M. Rothschild, and R. Wilson** (1997). "Introduction." *Journal of Economics and Management Strategy* 6(3): 425–430.
- Milgrom, P.** (2004). *Putting Auction Theory to Work*. New York: Cambridge University Press.
- Milgrom, P. and R. Wilson** (1993a). "Affidavit of Paul R. Milgrom and Robert B. Wilson." *Comments of PacBell* PP Docket No. 93–253.
- Milgrom, P. and R. Wilson** (1993b). "Replies to Comments on PCS Auction Design." *Reply Comments of PacBell*. PP Docket No. 93–253.
- Mirowski, P.** (forthcoming). "Markets Come to Bits." *Journal of Economic Behavior and Organization*.
- Mirowski, P., and K. Lee** (2003). "The Purest Form of Rationality is that which is Imposed." Notre Dame working paper.
- Murray, J.** (2002). *Wireless Nation*. Cambridge, MA: Perseus.
- Nalebuff, B. and J. Bulow** (1993a). "Designing the PCS Auction." *Comments of Bell Atlantic* PP Docket No. 93–253.
- Nalebuff, B. and J. Bulow** (1993b). "Response to PCS Auction Design Proposals." *Reply Comments of Bell Atlantic* PP Docket No. 93–253.
- Nik-Khah, E.** (2005). *Designs on the Mechanism: Economics and the FCC Spectrum Auctions*. Ph.D. thesis, University of Notre Dame.
- Parkin, M.** (1998). *Economics*, 4th ed. Reading, MA: Addison-Westley.
- Plott, C.** (1997). "Laboratory Experimental Testbeds: Application to the PCS Auction." *Journal of Economics and Management Strategy* 6(3): 605–638.
- Skrzycki, C.** (1993). "FCC Prepares to Carve up New Portable Phone Frontier." *Washington Post*. September 16, 1993: D10.
- Swedberg, R.** (2004). "On the Present State of Economic Sociology", *Economic Sociology: European Economic Newsletter* 5(2): 2–17.
- Thelen, J.** (1995). "Milgrom's Progress." *The Recorder*. May 8, 1995.
- Weber, R.** (1993a). "Comments on FCC 93-455." *Comments of TDS* PP Docket No. 93-253.
- Weber, R.** (1993b). "Reply to Comments on FCC 93-455." *Reply Comments of TDS* PP Docket No. 93-253.
- Weber, R.** (1997). "Making More from Less: Strategic Demand Reduction in the FCC Spectrum Auctions." *Journal of Economics and Management Strategy* 6(3): 529–548.