Market Mechanisms and the Efficient Use and Management of Scarce Spectrum Resources

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I. INTRODUCTION

In light of the rapid growth of demand for data transmission on mobile wireless networks, the Federal Communications Commission's ("FCC") 2010 National Broadband Plan proposed to increase the amount of spectrum available for flexible commercial use by 500 MHz by 2020, with 300 MHz of this additional spectrum available for mobile broadband use by 2015.[1] The National Broadband Plan proposes to increase significantly the amount of spectrum used for mobile communications service in the hopes of postponing the effects of spectrum exhaust in the U.S. mobile wireless industry.[2] Given the near total absence of fallow spectrum in the frequency bands useful for mobile broadband, satisfying the mobile wireless industry's appetite for spectrum will necessarily require a repurposing and reallocation of already-assigned spectrum.[3] While the National Broadband Plan identified some arguably low-hanging fruit,[4] the search for high-quality spectrum for commercial users continues. As a consequence, eyes are fixed on the federal government, whose agencies are assigned about half (1,687 MHz) of the "beachfront" spectrum between 225 MHz and 3.7 GHz.[5]

Although federal agencies need spectrum to carry out their mission-critical duties such as national defense and homeland security, public sector users have very weak incentives—if any—to use their spectrum efficiently. As one recent government-sponsored study concluded,

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1. FCC, CONNECTING AMERICA: THE NATIONAL BROADBAND PLAN 84 (2010) [hereinafter NATIONAL BROADBAND PLAN], *available at* http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-296935A1.pdf.

2. The U.S. wireless industry estimated it needed another 800 MHz of spectrum. *See, e.g.*, Reply Comments of CTIA–The Wireless Association at 2, A National Broadband Plan for Our Future, FCC Docket No. 09-51 (filed Nov. 13, 2009), *available at* http://fjallfoss.fcc.gov/ecfs/document/view?id=7020348306.

3. *See, e.g.*, T. Randolph Beard, George S. Ford, Lawrence J. Spiwak & Michael Stern, *Taxation by Condition: Spectrum Repurposing at the FCC and the Prolonging of Spectrum Exhaust*, PHX. CTR. POL'Y PAPER NO. 44 (Sept. 2012), *available at* http://www.phoenix-center.org/pcpp/PCPP44Final.pdf.

4. Sources of additional spectrum for mobile broadband include changing the rules for the Wireless Communication Services ("WCS") band and the Mobile Satellite Services ("MSS") bands, expanding the Advanced Wireless Services ("AWS") band, and auctioning the broadcast television band. NATIONAL BROADBAND PLAN, *supra* note 1, at 84–85.

5. *See generally* PRESIDENT'S COUNCIL OF ADVISORS ON SCI. & TECH., REPORT TO THE PRESIDENT: REALIZING THE FULL POTENTIAL OF GOVERNMENT-HELD SPECTRUM TO SPUR ECONOMIC GROWTH 8 (July 2012), *available at* http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast_spectrum_report_final_july_20_2012.pdf [hereinafter PCAST REPORT]; *see also* Ajit Pai, *Too Much Government, Too Little Spectrum*, REDSTATE (Jan. 3, 2013, 9:30 AM), http://www.redstate.com/ajitpai/2013/01/03/too-much-government-too-little-spectrum/; Juliana Gruenwald, *Wireless Industry Already Looking Ahead for More Spectrum*, NAT'L J. (Feb. 29, 2012) (quoting Charla Rath, Vice President for Wireless Policy, Verizon: "We need to be thinking about how we get a continuous supply of spectrum out there for commercial mobile wireless . . . . And, frankly, one of the key places to look is government spectrum . . . ."), http://www.nationaljournal.com/tech/wireless-industry-already-looking-ahead-for-more-spectrum-20120229.

"[f]ederal users currently have no incentives to improve the efficiency with which they use their own spectrum allocation . . . ." [6] Inefficiency in spectrum use implies that the same output could be produced using less of the scarce spectrum resource. Therefore, improving spectral efficiency in the public sector makes it possible to repurpose some government spectrum for commercial use while continuing to support essential public services. In light of the need for more spectrum resources in the commercial wireless sector, improving efficiency in the government's use and management of spectrum is a significant policy issue both in the United States and in other countries.[7] A number of studies have offered proposals aimed at increasing efficiency while continuing to meet the critical wireless communications needs of federal users.

The purpose of this Article is twofold. First, we turn to the standard production theory of economics to clarify what is normally meant by efficiency in the context of spectrum use. Using the same conceptual framework, prior studies, including several conducted by agencies of the U.S. government, have uniformly pointed to the efficiency of market outcomes as the gold standard for spectrum policy. Consequently, many of the proposals to improve the spectral efficiency of government users involve government agencies paying a market price, or a pseudo-market price, for the spectrum they use. Given our analysis, we are skeptical that such proposals—especially those calling for spectrum "markets" within the government—will ultimately lead to significant or long-term improvements in the public sector's efficiency in using its spectrum.

Second, we detail a theory of spectrum allocation across public and private users. In this model, we are not concerned with ways to improve the public sector's efficiency in its *use* of spectrum; rather, we address the questions of how government spectrum can be made available for commercial use, and how the government's inefficient *management* of spectrum influences the method of spectrum assignment. We envision two scenarios: (i) federal spectrum holdings continue to be managed by the government and leased to private sector users; or (ii) federal spectrum holdings are auctioned to and managed by the private sector for commercial uses.

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6. PCAST REPORT, *supra* note 5, at ix.

7. *See, e.g.*, J. SCOTT MARCUS, JOHN BURNS, FRÉDÉRIC PUJOL & PHILLIPA MARKS, FINAL REPORT: OPTIMISING THE PUBLIC SECTOR'S USE OF THE RADIO SPECTRUM IN THE EUROPEAN UNION 40 (Oct. 27, 2008) [hereinafter WIK-CONSULT REPORT], *available at* http://www.plumconsulting.co.uk/pdfs/Plum_Optimising_public_sector_spectrum_use_April_2010.pdf; EUROPEAN COMM'N, FINAL RSPG OPINION: BEST PRACTICES REGARDING THE USE OF SPECTRUM BY SOME PUBLIC SECTORS, RSPG09-258 (Feb. 2009) [hereinafter EU BEST PRACTICES], *available at* http://rspg-spectrum.eu/_documents/documents/opinions/rspg09_258_rspgopinion_pus_final.pdf; *see also* Kenneth R. Carter & J. Scott Marcus, Improving the Effectiveness and Efficiency of Spectrum Use by the Public Sector: Lessons from Europe 3, 7 (Sept. 27, 2009) (unpublished manuscript), *available at* http://ssrn.com/abstract=1488852.

Our model provides a number of policy-relevant findings. Among the more significant findings, we show that when all economic consequences are considered, the leasing of spectrum by the government for the production of private goods is less desirable than the auction of spectrum. The model also suggests that, under certain conditions, spectrum used by the government to produce public goods should be sold to the private sector and leased back to the government for the provision of public goods, in much the same way as the government buys other inputs from the private sector. Put bluntly, if the government is demonstrably incapable of managing and using spectrum resources efficiently—and most agree that this is historically the case—then it should not manage spectrum. Instead, if the goal of spectrum use and management is to enhance economic efficiency, then policymakers should expand the private sector's management of the nation's scarce spectrum resources, possibly including the management of spectrum used by federal agencies.

To be clear, we offer no specific mechanisms to improve the public sector's spectral efficiency, nor to transfer spectrum from the public to the private sector. As such, our analysis is not a panacea for spectrum policy; there is unlikely to be any single solution suitable for all spectrum bands and all public services. We do claim, however, that our approach carefully focuses attention on precisely those aspects of the spectrum allocation issue that must be understood in order for any reform effort to succeed. In essence, we take the contrarian position by arguing that the best solution to the government's inefficiency in spectrum use and management is neither "more" government nor a "more efficient" government, but rather the expansion of private sector management of the nation's scarce spectrum resources.

II. BACKGROUND

Heightened attention to government spectrum reform was stimulated by the National Broadband Plan's call to make available for commercial use an additional 500 MHz of spectrum, some of which is expected to come from the repurposing of federally assigned spectrum. Subsequent to the Plan's release in 2010, the White House released a Presidential Memorandum on spectrum use to the heads of all executive departments and agencies.[8] The National Telecommunications and Information Administration ("NTIA") released at least two reports on spectrum repurposing to help meet this goal.[9] The President's Council of Advisors

8. Unleashing the Wireless Broadband Revolution, 75 Fed. Reg. 38,387 (July 1, 2010).

9. NTIA, PLAN AND TIMETABLE TO MAKE AVAILABLE 500 MEGAHERTZ OF SPECTRUM FOR WIRELESS BROADBAND (Oct. 2010); NTIA, AN ASSESSMENT OF THE VIABILITY OF ACCOMMODATING WIRELESS BROADBAND IN THE 1755–1850 MHZ BAND (Mar. 2012). As discussed *infra*, these documents do not exhaust the government's coverage of this issue prior to the release of the National Broadband Plan.

on Science and Technology ("PCAST") also released a report on the issue that calls for, among other things, the abandonment of identifying, clearing and auctioning government spectrum for commercial use, in favor of a government-managed spectrum commons in which spectrum is "leased" to private sector users.[10] In addition to these recent reports, the Government Accountability Office ("GAO") has published a number of studies on the topic over the past decade or so, all of which are somewhat to very critical of the government's management of spectrum.[11] Outside of government research, recent studies on the topic of federal spectrum reform have been released by, for example, the Mercatus Center at George Mason

10. PCAST REPORT, *supra* note 5, at vi ("PCAST finds that clearing and reallocation of Federal spectrum is not a sustainable basis for spectrum policy due to the high cost, lengthy time to implement, and disruption to the Federal mission. . . . The essential element of this new Federal spectrum architecture is that the norm for spectrum use should be sharing, not exclusivity."); *see also* Kevin Werbach & Aalok Mehta, *The Spectrum Opportunity: Sharing as a Solution to the Wireless Crunch*, 8 INT'L J. COMM. 128, 129 (2014) ("The new normal of spectrum sharing may be difficult at first to accept. However, with today's technology, sharing arrangements can be structured to meet the requirements of many categories of users. Conversely, taking spectrum from government or private incumbents and selling it to wireless data providers is far simpler in concept than in execution today. Policy makers should follow the lead of the President's Council of Advisors on Science and Technology (PCAST) and the FCC, both of which have offered recent proposals to reorient spectrum policy around sharing."); *but cf.* George Ford, *Shared Spectrum is a Pipe Dream*, HILL (Feb. 6, 2014, 3:00 PM), http://thehill.com/blogs/congress-blog/technology/197569-shared-spectrum-is-a-pipe-dream ("Both licensed and unlicensed spectrum provides significant value to consumers. To adopt a blanket presumption of sharing for all new spectrum as Professor Werbach touts is simply inefficient and wasteful. Rather, the allocation decision should be made based on which licensing approach is expected to generate the greatest value for the spectrum being allocated.").

11. *See, e.g.*, U.S. GOV'T ACCOUNTABILITY OFFICE, GAO-11-352, SPECTRUM MANAGEMENT: NTIA PLANNING PROCESSES NEED STRENGTHENING TO PROMOTE EFFICIENT USE OF SPECTRUM BY FEDERAL AGENCIES (2011) [hereinafter GAO-11-352], *available at* http://www.gao.gov/new.items/d11352.pdf; U.S. GOV'T ACCOUNTABILITY OFFICE, GAO-12-1018T, SPECTRUM MANAGEMENT: FEDERAL GOVERNMENT'S USE OF SPECTRUM AND PRELIMINARY INFORMATION ON SPECTRUM SHARING (2012) [hereinafter GAO-12-1018T], *available at* http://www.gao.gov/assets/650/648206.pdf; U.S. GOV'T ACCOUNTABILITY OFFICE, GAO-13-472, SPECTRUM MANAGEMENT: FEDERAL RELOCATION COSTS AND AUCTION REVENUES (2013), *available at* http://www.gao.gov/assets/660/654794.pdf; U.S. GOV'T ACCOUNTABILITY OFFICE, GAO-06-526T TELECOMMUNICATIONS: OPTIONS FOR AND BARRIERS TO SPECTRUM REFORM (2006), *available at* http://gao.gov/assets/120/113012.pdf; U.S. GOV'T ACCOUNTABILITY OFFICE, GAO-06-236, TELECOMMUNICATIONS: STRONG SUPPORT FOR EXTENDING FCC'S AUCTION AUTHORITY EXISTS, BUT LITTLE AGREEMENT ON OTHER OPTIONS TO IMPROVE EFFICIENT USE OF SPECTRUM (2005); U.S. GOV'T ACCOUNTABILITY OFFICE, GAO-04-666, SPECTRUM MANAGEMENT: BETTER KNOWLEDGE NEEDED TO TAKE ADVANTAGE OF TECHNOLOGIES THAT MAY IMPROVE SPECTRUM EFFICIENCY (2004), *available at* http://www.gao.gov/new.items/d04666.pdf; U.S. GOV'T ACCOUNTABILITY OFFICE, GAO-04-1028, INTERDEPARTMENT RADIO ADVISORY COMMITTEE: IRAC REPRESENTATIVES EFFECTIVELY COORDINATE FEDERAL SPECTRUM BUT LACK SENIORITY TO ADVISE ON CONTENTIOUS POLICY ISSUES (2004), *available at* http://gao.gov/assets/250/244315.pdf; U.S. GOV'T ACCOUNTABILITY OFFICE, GAO-02-906, TELECOMMUNICATIONS: BETTER COORDINATION AND ENHANCED ACCOUNTABILITY NEEDED TO IMPROVE SPECTRUM MANAGEMENT (2002) [hereinafter GAO-02-906], *available at* http://www.gao.gov/assets/240/235811.pdf.

University,[12] Public Knowledge,[13] and the Technology Policy Institute ("TPI").[14] And, as noted above, the effort to improve efficiency in the public sector's spectrum use is not just a domestic endeavor; the European Commission has recently sponsored a number of studies that offer conscientious examinations of public spectrum use and policy options.[15]

With this flurry of recent attention, it is natural to think this issue is a new one. It is not. Some GAO studies on the topic are now over ten years old,[16] and President George W. Bush issued a Presidential Memorandum in May 2003 calling for a "Spectrum Policy Initiative" aimed at leading to the "development of legislative and other recommendations for improving spectrum management procedures and policies for the Federal Government and to address State, local and private spectrum uses."[17] Yet even these now-dated efforts seem recent when considering that a thorough investigation of federal spectrum use was initiated nearly a quarter-century ago by the NTIA in a proceeding that culminated in its *1991 Spectrum Report*.[18] The NTIA's report was comprehensive and innovative,[19] calling

12. Brent Skorup, *Reclaiming Federal Spectrum: Proposals and Recommendations* (Mercatus Ctr., Working Paper No. 13-10, 2013) [hereinafter *Mercatus Report*], *available at* http://mercatus.org/sites/default/files/Skorup_FederalSpectrum_v1[1].pdf, *subsequently republished in* 15 COLUM. SCI. & TECH. L. REV. 90 (2012).

13. HAROLD FELD & GREGORY ROSE, PUBLIC KNOWLEDGE, BREAKING THE LOGJAM: SOME MODEST PROPOSALS FOR ENHANCING TRANSPARENCY, EFFICIENCY AND INNOVATION IN PUBLIC SPECTRUM MANAGEMENT (2010) [hereinafter PK REPORT], *available at* http://www.publicknowledge.org/pdf/pk-fed-spectrum-transparency-whitepaper.pdf.

14. THOMAS M. LENARD, LAWRENCE J. WHITE & JAMES L. RISO, TECH. POL'Y INST., INCREASING SPECTRUM FOR BROADBAND: WHAT ARE THE OPTIONS? (2010) [hereinafter TPI REPORT], *available at* http://www.techpolicyinstitute.org/files/increasing_spectrum_for_broadband1.pdf.

15. *See* EU BEST PRACTICES, *supra* note 7.

16. *See* sources cited *supra* note 11.

17. Presidential Memorandum on Spectrum Policy for the 21st Century, 69 Fed. Reg. 1568, 1569 (Jan. 9, 2004), *available at* http://www.ntia.doc.gov/files/ntia/publications/presmemoonspectrumpolicy.pdf.

18. *See* NTIA, *U.S. Spectrum Management Policy: An Agenda for the Future* (1991), http://www.ntia.doc.gov/report/1998/us-spectrum-management-policy-agenda-future [hereinafter *1991 Spectrum Report*]. The *1991 Spectrum Report* was the final stage of the process initiated by the *Comprehensive Policy Review of Use and Management of the Radio Frequency Spectrum*. Notice of Inquiry, 54 Fed. Reg. 50,695–96 (Dec. 8, 1989). A number of government studies predated this piece. *See, e.g.*, *1991 Spectrum Report*, *supra*, at n.616 (citing F. Hopkins & W. Schummer, NTIA, *Development of a Methodology for Improved Use of the Electromagnetic Spectrum by Federal Agencies*, ORI, Contract 50-SANT-4-03565 (1985)); *id.* at n.470 (citing OTP, *Management of Federal Spectrum Use Through Shadow Prices: Can It Be Rendered Practicable?* (technical proposal submitted by Gen. Elec. Co.–TEMPO Ctr. for Advanced Studies) (Apr. 3, 1972); OTP, *Paying for Airwaves Use: Concept and Experiment for Including the Economic Value of Spectrum in OTP/IRAC Process to Allocate and Assign Airwaves Use Within the U.S. Government* (June 1973); C.B. Thompson, *Economic Efficiency and the Allocation, Allotment, and Assignment of Government Spectrum Space* (Mar. 1973); OTP, *The Possible Effects of a System of User Charges for Spectrum on the Use of the 2700–2900 MHz Band, 1956–1972* (March 1973); James H. Alleman, Office of Telecomms., U.S. Dep't of Commerce, *The Shadow Price of Electromagnetic Spectrums: A Theoretical Analysis* (July 1974)).

19. This report is stunningly contemporary in its discussion of spectrum, as

for better spectrum accounting, improved databases, more spectrum sharing (e.g., cognitive radios), and injecting a heavy dose of market discipline into spectrum allocation and administration to drive public sector efficiency. For all practical purposes, recent studies on spectrum policy largely reiterate the findings and recommendations of the *1991 Spectrum Report*. (One may go even further back to the seminal work by Ronald Coase from the early 1960s on spectrum allocation, though his writings were not focused exactly on the specific issues we address in this paper.[20])

Dating from the NTIA's proceeding and report, the reform effort is now at least three decades old, yet, as the government admits, almost no progress has been made. As the GAO concluded in 2011, "[the] NTIA has been directed to conduct several projects focused on reforming government wide federal spectrum management and promoting efficiency among federal users of spectrum; however, its efforts in this area have resulted in limited progress toward improved spectrum management."[21] Similarly, the *PCAST Report* concludes, "[t]here is . . . a long history of failed attempts to implement significant reforms in Federal spectrum use."[22] Despite the recognition of inefficient use and management of spectrum by the government for at least a quarter-century, today the government admits there are still no incentives for efficient spectrum use by federal agencies.[23]

Efficiency has diverse meanings, so it is important to first consider exactly what the prior research means when it labels public use as "inefficient."[24] For this purpose, we turn to basic production theory, a textbook economic principle that seeks to explain how firms use resources to produce goods and services.[25] In the next two sections, we show that the most commonly proffered solution to the efficiency issue—that is, forcing the government to face the market price of spectrum—may help in some ways, but it is not a panacea to federal agencies' inefficient use or management of spectrum over the long term.[26] Many details must be addressed if such efforts are to be effective, including, especially, how spectrum prices are set and how the levy of spectrum fees impacts the budgets of government agencies. More critically, the government is not a

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demonstrated by its introductory comments: "Use of the radio spectrum is crucial to U.S. communications, and indeed, the national economy. . . . Current spectrum management policies . . . are under increasing strain as the demand for existing spectrum-based services grows, and new spectrum-related technologies and applications emerge." *1991 Spectrum Report*, *supra* note 18, at 1.

20. *See generally* R. H. Coase, *The Federal Communications Commission*, 2 J.L. & ECON. 1 (1959); R. H. Coase, *The Interdepartment Radio Advisory Committee*, 5 J.L. & ECON. 17 (1962); *see also* Harvey J. Levin, *Spectrum Allocation Without Market*, 60 AM. ECON. REV. (PAPERS & PROC.) 209 (1970).

21. GAO-11-352, *supra* note 11, at 9.

22. PCAST REPORT, *supra* note 5, at 55.

23. *Id.* at ix.

24. For a discussion of efficiency, see also WIK-CONSULT REPORT, *supra* note 7, at 2.

25. *See* SVEND RASMUSSAN, PRODUCTION ECONOMICS: THE BASIC THEORY OF PRODUCTION OPTIMISATION 1–3 (2d ed. 2013) (explaining the basics of production theory).

26. A similar conclusion is reached in WIK-CONSULT REPORT, *supra* note 7, at 62, 63.

profit-driven entity; yet, it is the pursuit of profits in a competitive setting that drives efficiency. How to resolve this underlying defect in incentives is a mystery.

We do not mean to imply that the effort to introduce better incentives through "market" pricing should be abandoned. Indeed, such efforts should be encouraged. We argue instead, in Part V, that the existing proposals do not go far enough. Our main concern is not so much about the inefficient *use* of spectrum as it is the inefficient *management* of spectrum.

III. INEFFICIENT USE OF SPECTRUM BY GOVERNMENT

It is widely-accepted that the government does not use and does not have incentives to use its spectrum assets efficiently. The *PCAST Report*, for example, states plainly, "[f]ederal users currently have no incentives to improve the efficiency with which they use their own spectrum allocation . . . ."[27] Likewise, the GAO concludes, federal users "have little economic incentive to otherwise use spectrum efficiently . . . ."[28] The European Commission's *WIK-Consult Report* states that "public sector agencies may not face sufficient incentives to make maximally economically efficient use of their spectrum assignments (e.g., through sharing with other compatible uses), or to give spectrum back to the spectrum management authority if they no longer need it."[29] An important question is what is meant by "inefficiency" in the context of spectrum use.

A. Economics of Inefficient Use

Spectrum must be combined with capital equipment, such as cell towers and wireless communications devices, to be useful. Labeling public spectrum use as "inefficient" normally implies an excessive use of spectrum in the capital-spectrum input mix—that is, too much spectrum is used given the production technology and the relative market prices of spectrum and capital.[30] We use the standard economic model of production and the related problem of cost minimization (or profit maximization) to shed considerable light on the assumptions underlying much of this discussion about the inefficiency of government spectrum use.[31] In fact, we

27. PCAST REPORT, *supra* note 5, at ix.

28. GAO-12-1018T, *supra* note 11, at 12.

29. WIK-CONSULT REPORT, *supra* note 7, at 7.

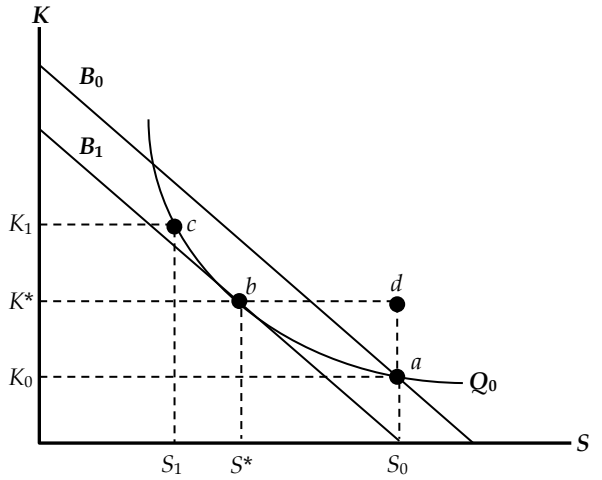
30. *See, e.g.*, OFFICE OF MGMT. & BUDGET, CIRCULAR NO. A-11, at § 31.12 (2013), *available at* http://www.whitehouse.gov/sites/default/files/omb/assets/a11_current_year/a11_2013.pdf ("In some cases, greater investments in systems could enhance Federal spectrum efficiency (e.g., purchase of more expensive radios that use less bandwidth); in other cases, the desired service could be met through other forms of supply (e.g., private wireless services or use of land lines).").

31. The FCC uses this approach in its report. *See* FCC, MOBILE BROADBAND: THE BENEFITS OF ADDITIONAL SPECTRUM (Oct. 2010), *available at* http://download.broadband.gov/plan/fcc-staff-technical-paper-mobile-broadband-benefits-of-additional-spectrum.pdf.

show that this standard textbook economic reasoning leads to some rather surprising conclusions on the likely consequences of schemes aimed at promoting public efficiency through a spectrum pricing mechanism.

To begin, consider Figure 1 below. A hypothetical federal agency produces a collection of goods and services Q_0 using two broad classes of inputs: spectrum (labeled *S*) and other goods (e.g., capital equipment, labeled *K*). The curve labeled Q_0 illustrates an isoquant whereby possible combinations of *S* and *K* that can, with efficient application, produce Q_0. The shape of isoquant Q_0 indicates the degree to which one class of inputs can be substituted for another, a consequence of the many various ways in which the same goods can ordinarily be produced. The conventional convex shape of Q_0 reflects the limitations of such substitution—that it becomes increasingly difficult as it is pursued to extremes. That is, the less spectrum the producer has, the greater the amount of other goods is required to maintain a fixed level of output.[32] The isoquant Q_0 also indicates only those combinations of *S* and *K* that are "technically efficient," i.e., that represent combinations of inputs such that no input can be reduced in use without some countervailing increase in another. In other words, all combinations of *S* and *K* that lie on Q_0 are efficient, in the sense that no input is literally being wasted.

Figure 1. Government's Inefficient Use of Spectrum



The FCC paper mistakenly labels the isoquant as an "indifference curve," the latter of which describes tradeoffs in consumption rather than production. *Id.* at 7. This discrepancy in the use of terminology does not meaningfully affect the conclusions drawn from the analysis.

32. For example, compare the additional amount of spectrum required to move from point *c* to *b* (S_1 to S^*) versus an equivalent reduction in *K* from *b* to *a*, which requires a much larger increase in spectrum to hold output constant (S^* to S_0).

Suppose that the agency in question has been directed by Congress to produce Q_0, and the agency is provided with resources sufficient to this task. Initially, these resources consist of the "free" spectrum S_0 and funds sufficient to purchase other goods in amount K_0, thus making the provision of Q_0 feasible through the inputs (S_0, K_0). *If the agency behaves efficiently*—that is, it allocates its budget and resources in a *technically* efficient way—then Q_0 will be produced using (S_0, K_0). Significantly, the agency in question appears to be behaving efficiently, and indeed it is in the technical sense. However, its efficiency is directed solely towards its selection of K: the amount of S the agency uses is usually selected for it. Notably, combinations of S and K lying above Q_0 (say d), which we might reasonably assume are all also capable of producing Q_0, are technically inefficient, i.e., literally wasteful.[33] The combination (S_0, K^*) is more costly than (S_0, K_0), yet it produces the same output. This result illustrates one meaning of the "inefficiency" in public use of spectrum—*technical inefficiency*. Although it is tempting to say that the agency "pretends that the spectrum is free,"[34] this is not really so: the agency consumes the amount of spectrum it is allocated, and no more. In contrast, if spectrum were truly "free"—that is, priced at zero—then the agency may wish to consume more than its allotment. Rather, if the agency is technically efficient, and carries out its mandate, then it will purchase the minimum amount of K necessary to fulfill its task (i.e., K_0 in the figure). Whether or not technical efficiency can be reasonably expected of federal agencies is a question beyond the scope of this Article.

It is not necessarily technical efficiency that presents the problem with the public sector's use of spectrum. Instead, as prior research has found, the relevant inefficiency in the agency's production of Q_0 arises because the input S_0 has an opportunity cost: this spectrum could be used to produce other goods or services. Thus, the issue is one of *allocative* efficiency, which turns on whether goods and services are allocated so as to maximize social welfare (i.e., where marginal benefits equal marginal costs). In the market setting, the value of this alternative use is given by the market value of the spectrum S_0. In simple terms, suppose the input S has a fair market value of P per unit. If the price of a unit of the input K is \$1, then the agency is producing the output Q_0 at a social cost of $P \cdot S_0 + K_0$. We denote this amount of money as B_0, which is the agency's "implicit budget" for producing Q_0. The set of all combinations of inputs S and K which cost an amount equal to the implicit budget of the agency are just those input combinations which satisfy the formula $P \cdot S + K = B_0$. This set of inputs lies on the straight line B_0 in Figure 1. Notice two features of this line: First, B_0 passes through the point (S_0, K_0), because S_0, K_0 costs B_0.

33. For example, at point d, inputs K^* and S_0 are used to produce Q_0, where the same output could be producing using K^*, S^*.

34. WIK-CONSULT REPORT, *supra* note 7, at 51 ("This is in contrast to the administrative approach in which spectrum requirements are expressed assuming the spectrum is in effect costless or 'free.'").

Second, though, B_0 is shown as being steeper than Q_0 at the point (S_0, K_0). This is an intentional choice; its meaning will become apparent below.

B. Pricing Spectrum to Improve Efficiency—Or Not

We consider now the possibility of implementing a price mechanism for spectrum, *S*, in attempt to induce the agency to adopt a more efficient allocation. Since the conversation about federal spectrum reform is largely about shifting public spectrum assignments to the commercial sector to alleviate spectrum shortages, either as exclusive licenses or via a sharing paradigm, the basic problem is presumably public agency overuse—not underuse—of spectrum.[35] We imagine that, from a social perspective, the agency is *overprovided* with spectrum; as such, our goal is to reduce public use. This scenario corresponds to the situation in Figure 1, in which B_0 is steeper than Q_0 at the point (S_0, K_0). In this case, we note that the implicit agency budget, B_0, is actually sufficient to buy more of both inputs *S* and *K* than is needed to produce Q_0. Therefore, the agency's operations are economically inefficient, as they overuse spectrum and underuse other goods.

The extent of the social inefficiency implied by the input choice (S_0, K_0) can be easily illustrated. Suppose the hypothetical budget amount B_0 were to decrease until it reached a level B_1 at which the input combination (S^*, K^*) were just affordable (i.e., $P \cdot S^* + K^* = B_1$). Economists term the input choice (S^*, K^*) "economically efficient" or "cost minimizing," because the input choice (S^*, K^*) is the smallest budget that can technically produce Q_0. The inefficiency of the original choice (S_0, K_0) thus has a dollar cost of $B_0 - B_1$. Assuming technical efficiency in the choice of *K* given S_0, the "overuse" or "inefficient use" of spectrum is thus represented monetarily by the amount $S_0 - S^*$.

This simple production model is the same implicit (and sometimes explicit) model used in prior research on the topic. The nature of the problem, as presented here, is expressed plainly in the European Commission's *WIK-Consult Report*:

> The public sector has typically been given or gifted the spectrum that it uses (which is to say that the spectrum has been provided at no cost, in much the same way that state owned land has often been gifted for public sector purposes), and is expected to use the resource to deliver outputs that are specified through the political process. There is not, however, a fixed relationship between spectrum and the output of public

35. One could imagine, for example, a system in which government agencies were given very limited spectrum and then prohibited from acquiring more. In such a case, our hypothetical conscientious agency would do the best it could by buying large amounts of *K* to make its very limited amount of *S* sufficient to produce Q_0. This outcome, though possible, is not the situation that motivates us here.

> sector agencies. These agencies have choices over the amounts of other complementary inputs they may purchase (e.g., radios and transmission equipment, transmission sites and the like), all of which affect their spectrum demand. Other complementary inputs are not free; consequently, there will be a tendency to use more spectrum (which is either free or low cost) and less of other inputs where such choices exist. If spectrum is scarce and so has a non-zero opportunity cost, then gifting spectrum will predictably result in an economic distortion and an inefficient use of the resource.[36]

We find a similar description of the efficiency problem in the *PCAST Report*:

> [T]he lack of spectrum pricing means that no visible budget expense is associated with overall Federal spectrum use, and thus hides the true social cost of that use, which is measured in terms of other uses of the spectrum that are precluded by current Federal use (the "opportunity cost").[37]

Furthermore:

> Under the current "command and control" system, Federal users obtain no reward for reducing their own need for spectrum . . . . [T]he absence of pricing signals that would push agencies toward making capital investments to improve efficiency over time tends to build up larger problems in the future: agencies have little or no reason to invest in technologies that could improve spectrum efficiency because they see little or no benefit from any resulting economies.[38]

These statements reveal the nature of the inefficiency of government spectrum use (allocative inefficiency), which results partially from the "absence of pricing signals."[39] Given this defect, it is unsurprising that studies on the topic, both in the United States and abroad, encourage the migration to an approach that requires public agencies to pay "market" prices for spectrum. For example, the *PCAST Report* concludes:

> Requiring Federal agencies to purchase spectrum rights through a market mechanism would go a long way toward achieving transparency, accountability, and efficiency in Federal spectrum use. It would therefore be desirable to move

36. WIK-CONSULT REPORT, *supra* note 7, at 51.
37. PCAST REPORT, *supra* note 5, at 55.
38. *Id.*
39. *Id.*

> quickly to a market mechanism so that Federal uses reflect their true social resource cost.[40]

In this statement, the *PCAST Report* establishes as the efficiency standard the market outcome, where the "true social resource cost" of spectrum is realized. Similarly, the NTIA's *1991 Spectrum Report* concludes that a "fee system for federal government spectrum users [could] encourage greater spectrum efficiency among such users . . . ."[41] The European *WIK-Consult Report* lays this argument out clearly:

> Economic incentives are generally best provided through markets. The purpose of market-inspired approaches to spectrum management in the private sector is to use prices to provide users with incentives to demand spectrum at the level that maximizes economic and social welfare. This is in contrast to the administrative approach in which spectrum requirements are expressed assuming the spectrum is in effect costless or "free". [42]

Furthermore, as the *WIK-Consult Report* states:

> As a general rule, welfare is maximised by setting input prices equal to opportunity cost and targeting policy interventions on the desired outputs.[43]

These studies and others on the public sector's use and management of spectrum uniformly make an appeal for an expanded role of market mechanisms in spectrum policy. The NTIA's *1991 Spectrum Report* calls for a "greater reliance on market principles;"[44] the *WIK-Consult Report* concludes, "there is a good case for the public sector to pay a price for spectrum that reflects its opportunity cost;"[45] and the *PCAST Report* states that it is "desirable to move quickly to a market mechanism so that Federal uses reflect their true social resource cost."[46] While debate persists over how to best introduce market forces to government spectrum use (e.g., auctions, spectrum fees, and so forth), nearly every study on the topic establishes the *market* outcome as the target standard for efficiency. With market outcomes as the stated goal, sensible public policy would focus on ways to transfer spectrum management to the private sector. Yet, this has not been case. In the next sections, we summarize some of the various

40. *Id.*
41. *1991 Spectrum Report*, *supra* note 18, at 2.
42. WIK-CONSULT REPORT, *supra* note 7, at 50–51.
43. *Id.* at 52 (footnote omitted).
44. *1991 Spectrum Report*, *supra* note 18, at 9.
45. WIK-CONSULT REPORT, *supra* note 7, at 52.
46. PCAST REPORT, *supra* note 5, at 55.

"ghost" market mechanisms proposed to address the failures of government policy to promote spectral efficiency, and illustrate why these particular "market" proposals—while perhaps constructive initial ideas—are not sufficient to induce fully efficient behavior by government agencies.

IV. THE EFFICACY OF EXISTING PROPOSALS TO IMPROVE GOVERNMENT'S EFFICIENT USE OF SPECTRUM

To date, many conscientious commentators have set forth various proposals to improve efficiency in the public sector's use of spectrum.[47] These proposals include, but are certainly not limited to, the imposition of spectrum fees (in the form of a "General Services Administration" or "GSA-style" approach), a "spectrum inventory" approach, and a proposal to create artificial currencies traded among government users ("spectrum currency").[48] All of these proposals follow directly from the economic model of production discussed in the previous section.[49] While we encourage policymakers to continue efforts to introduce market-based solutions to the problem, for the reasons set forth below, we do not believe these particular proposals represent an effective long-term solution to improving the efficiency of the government's use of spectrum.

A. The "GSA Model"

Like office furniture, telephone services, and labor, spectrum is an input of production for government agencies. With the exception of spectrum, government agencies typically acquire the inputs of production from the market. With efficiency as the objective, it is natural to propose that government agencies likewise pay for the spectrum they use. Absent paying market prices, it is argued that the agencies will not recognize the full social cost of using the spectrum.[50] A commonly proposed approach to imposing market discipline on the public sector is based on the way federal agencies pay for office space, which involves paying the General Services Administration ("GSA") rental fees that are putatively based on market rates for local real estate. As observed in the *PCAST Report*, "Spectrum use fees would be monetary charges levied on agencies for spectrum use and

47. *See* discussion *supra* notes 12–14.

48. *See* sources cited *supra* note 11.

49 *See* discussion *supra* Part II.A.

50. *See, e.g.*, COLEMAN BAZELON & GIULIA MCHENRY, BRATTLE GRP., SPECTRUM SHARING: TAXONOMY AND ECONOMICS 43 (Feb. 6, 2014), *available at* http://www.brattle.com/system/news/pdf2s/000/000/617/original/Spectrum_Sharing_-_Taxonomy_and_Economics_Full_Report.pdf?1391695199 ("If federal users paid for its use, they would internalize the cost associated with holding spectrum assignments that prevent other productive uses of the frequencies. Recognizing the costs of spectrum would incentivize federal users to adjust their usage to reduce costs.").

paid to the U.S. Treasury. Use fees would be similar to rent paid to the GSA for office space in government-owned buildings."[51]

The TPI Report also discusses this proposal:

> One simple model for exploration in this direction is based on the market-oriented rental rates that agencies are charged when they lease space in buildings that are owned (or leased) by the U.S. Government Services Administration (GSA). The GSA's Federal Buildings Fund (FBF) provides recognition of the opportunity costs of those buildings. The government agencies make rental payments to GSA, which can use the money to acquire additional property if necessary. These rental payments provide an incentive for government agencies to economize on space.[52]

Similarly, the *Mercatus Report* concludes, "Congress should also require agencies to pay for the spectrum they possess, just as agencies pay market prices for other inputs."[53] And the *WIK-Consult Report* suggests that "[t]here are different ways in which this payment could be implemented; the public sector could bid for spectrum at auction, could buy spectrum through trades, or could pay a price set by the regulator (a practice known as *Administrative Incentive Pricing*, or *AIP*)."[54]

Despite its wide appeal, however, there are a number of problems with this "spectrum fee" approach, some more significant than others. Here, we discuss three concerns, although there are certainly many others. First, at its best, such an approach is only a "ghost market" solution, because prices are not established in a real market setting; instead, another government agency establishes the prices.[55] Obviously, price-setting in this environment may be manipulated by political forces.[56] Prior to fully

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51. PCAST REPORT, *supra* note 5, at 55; *see also* U.S. DEP'T OF COMMERCE, SPECTRUM MANAGEMENT FOR THE 21ST CENTURY: THE PRESIDENT'S SPECTRUM POLICY INITIATIVE PROGRESS REPORT FOR FISCAL YEAR 2007 (Nov. 2008), *available at* http://www.ntia.doc.gov/legacy/osmhome/spectrumreform/FY2007%20Progress%20Report_for_Fiscal_Year_2007_Final_25Nov08_rev_1Dec08.pdf; U.S. DEP'T OF COMMERCE, SPECTRUM MANAGEMENT FOR THE 21ST CENTURY: PLAN TO IDENTIFY AND IMPLEMENT INCENTIVES THAT PROMOTE MORE EFFICIENT AND EFFECTIVE USE OF SPECTRUM (2008), *available at* http://www.ntia.doc.gov/files/ntia/publications/incentives_plan.pdf.

52. TPI REPORT, *supra* note 14, at 26 (footnote omitted).

53. *Mercatus Report*, *supra* note 12, at 2.

54. WIK-CONSULT REPORT, *supra* note 7, at 52.

55. *See id.* at 18 n.11 ("The use of Administrative Incentive Pricing (AIP) is market-inspired, but it is not market-based (because the price has not been set by the market) . . . .").

56. *See, e.g.*, *id.* at 45 ("[T]he management of public spectrum is delegated to sectoral bodies (who are sometimes the spectrum user). A problem that this can lead to is that the manager may seek to keep all of its allocation for its own use (rather than sharing/releasing spare spectrum for use by others), particularly if incentives to do otherwise are weak."); *id.* at 49 ("[I]t is often the case that major public sector spectrum users do not pay any spectrum fees; moreover, fees are often set at levels far less than those required to recover the

embracing the GSA model of spectrum pricing, we believe a detailed study comparing the GSA's practices with actual market outcomes is warranted.

Second, the sources of data with which a GSA-type organization would set prices must be established. Real estate is a very active market, both in rentals and sales, and data is easily obtained—but publicly available information on spectrum transactions is limited. The paucity of public data does not suggest such transactions are few; indeed, there are many smaller-scale transactions for spectrum, both in the form of sales and leases, but the details of these deals are often not reported in public documents. Without doubt, commercial wireless carriers are very capable at valuing spectrum and do so regularly.[57] Whether these methods are proprietary and useful for setting prices for public use is an important question.

Third, if federal agencies are required to pay "market prices"—or for that matter, any price—for spectrum, then agencies' expenses will rise by that amount (at least, initially). Most likely, the agencies will seek from Congress a budget adjustment for such expenses. How a federal agency's budget is affected by the spectrum fees influences the agency's incentives, an issue to which we now turn.

We can use the simple production analysis above to analyze the spectrum fee (or GSA-style) model for public spectrum use. We will restrict our attention here to one of the more plausible ideas: suppose some central government authority imposed a price on spectrum use, so that agencies would in fact have to pay for what they previously received without charge. Moreover, suppose the charge implemented for S was in fact the market price P. However, because the agency has a responsibility to produce Q_0, we assume it will be provided with some means (or budget) for doing so. There are several ways by which the needed financial supplement could be calculated. We assume in what follows that the agency's appropriation for K is set "correctly"—i.e., at the minimum level necessary to see that Q_0 is produced given the agency's choice of S.[58]

First, and most simply, suppose the agency were charged P per unit of S used, and was simultaneously given a supplemental appropriation exactly equal to its spending on spectrum, $P{\cdot}S$.[59] In this case, of course, it is feasible for the agency to do nothing whatsoever: if it selected S_0 (its current allotment), then it would receive a supplement of $P{\cdot}S_0$, exactly offsetting the agency's liability for "purchasing" S. Plainly, to continue to produce Q_0, complete inaction is feasible. A move toward the efficient mix of inputs is expected from private firms because they seek profit

opportunity cost of spectrum . . . .").

57. There are hundreds of transactions involving the lease of spectrum between commercial providers, as detailed in the FCC's Universal Licensing System, which is available at http://wireless.fcc.gov/licensing/index.htm?job=spectrum_leasing#d36e70. *See also* WIK-CONSULT REPORT, *supra* note 7, at 51 ("For the private sector, the use of spectrum auctions is well established.").

58. Again, we assume technical efficiency, which may not occur in practice.

59. This is the present GSA-style model.

maximization. But federal agencies do not necessarily seek to maximize their profits—or minimize their costs.[60] There is no inherent incentive for the agency to alter its spectrum allocation or to use spectrum more efficiently.

But what if the agency selected a different level of *S* under this scenario? Any such choice in the direction of S^* would be more socially efficient, but would also reduce the agency's budget. If the agency could be relied upon to minimize costs regardless of the consequences to its budget, then confronting the agency with the "right prices" would, in theory, suffice to induce it to behave efficiently, in an allocative sense. The difficulty is the venerable observation that government agencies rarely move aggressively to cut their own budgets.[61] In fact, the budget consequences of such a plan led the authors of the *PCAST Report* to reject altogether the use of spectrum fees, concluding that "practical difficulties . . . would render it ineffective."[62] The only "practical difficult[y]" listed in the *PCAST Report* is the fear that any reduction in spectrum usage accompanied by compensation from the commercial or public sector, or merely reflecting some reduction in a government-created "usage fee" regime, would lead Congress to trim the budget of the agency by a commensurate amount.[63] As the *PCAST Report* states:

> [T]he introduction of spectrum fees would not necessarily remove or even significantly diminish the obstacles individual agencies face in trying to evolve their spectrum use in ways that would maximize efficiency by the Federal Government as a whole. In particular, an agency would legitimately fear that if it were to relinquish $500 million of spectrum use, and reduce its fee payment accordingly, it would later see its budget reduced by much of that $500 million and therefore see little or no benefit for its efforts. For that reason, we do not think a spectrum fee system is likely to be an effective way to promote Federal efficiency in spectrum use.[64]

In effect, the "practical difficult[y]" of the "usage fee" approach stems from budgetary actions by Congress, which work against the more efficient use of spectrum. Similarly, as the *WIK-Consult Report* observes:

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60. *See, e.g.*, TPI REPORT, *supra* note 14, at 23 ("[G]overnment agencies do not operate in a market context, and profit maximization is not their goal.").

61. *Cf.* T. Randolph Beard, George S. Ford, Hyeongwoo Kim & Lawrence J. Spiwak, *Regulatory Expenditures, Economic Growth and Jobs: An Empirical Study*, PHX. CTR. POL'Y BULL. NO. 28 (Apr. 2011), *available at* http://www.phoenix-center.org/PolicyBulletin/PCPB28Final.pdf.

62. PCAST REPORT, *supra* note 5, at 55.

63. *Id.*

64. *Id.*

> For these policies to be beneficial, however, changes may be required in the way that the public sector agencies operate. It is often argued that charging for spectrum use by the public sector is just a "money go round" with no beneficial effects. This argument is correct if the public sector user cannot benefit from any saving in its spectrum costs. This means that for market-inspired mechanisms to be effective in the public sector, budgetary arrangements need to be sufficiently flexible to allow public sector organisations to "profit" from economising on spectrum use, including the ability to increase or decrease their expenditure on spectrum use (where this is thought to be necessary) within their overall budget constraints.[65]

Simple production economics suggests that imposing "market prices" on federal agencies may not be sufficient to induce efficient behavior. Indeed, complete inaction is a viable choice, as it would likely impose no costs on the agency.[66] Absent a change in incentives, market pricing is not sufficient for meaningful reform.[67] Plainly, the design of "market" mechanisms for federal agencies must explicitly consider the budget process and its effects on the incentives that process provides to increase the efficiency of spectrum use.[68] Thus, the problem with the spectrum fee approach is more one of incentives than of technical feasibility.[69] As we see it, *it seems unlikely that the sole reason the government is inefficient is that its decision-makers do not face the correct prices*. Even if the agency did face market prices, federal agencies are not profit-maximizing entities, are not permitted to offer spectrum in the secondary market, and are strongly motivated by budgetary considerations.[70]

B. Setting the Efficient Level of Spectrum Use

A second way to compensate the agency for spectrum is to set the supplemental appropriation not based on how much spectrum the agency actually buys, but rather on the amount it *should* buy. Prior research on this

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65. WIK-CONSULT REPORT, *supra* note 7, at 52.

66. *See, e.g.*, TPI REPORT, *supra* note 14, at 23 ("From the agency's perspective . . . the spectrum is a free resource, for which it pays no rent or upkeep costs. The perceived opportunity costs of spectrum are small at best, since there is no market for this spectrum.").

67. *See* WIK-CONSULT REPORT, *supra* note 7, at 52.

68. *See* PCAST REPORT, *supra* note 5, at 55.

69. *See* WIK-CONSULT REPORT, *supra* note 7, at 52; PCAST REPORT, *supra* note 5, at 55.

70. *See, e.g.*, TPI REPORT, *supra* note 14, at 23 ("[E]ven if there were an active spectrum market . . . and even if a government agency were interested in increasing the resources that are at its disposal . . . . If an agency were to sell its spectrum, the agency's net gain might be far smaller than the selling price . . . due to budget reallocations that would net out the agency's gain.").

topic often suggests such efforts.[71] In the example at hand, this calls for a fixed payment of $P \cdot S^*$, regardless of the agency's choice of S. In this case, the only way the agency could fulfill its charge to produce Q_0 is by selecting the efficient inputs (S^*, K^*). This approach is theoretically attractive, but in practice it means that the agencies themselves—or, more plausibly, some oversight agency—would be charged with determining the cost-minimizing plans, an extremely daunting task. Some agencies might be confronted with very significant adjustments in their budgets. As the GAO has noted:

> NTIA has several oversight activities to encourage accountability and efficient use of the spectrum by federal agencies, but federal officials stated that the effectiveness of these activities is hindered by staffing and resource shortages. Specifically, NTIA has directed federal agencies to use only as much spectrum as they need and has established frequency assignment and review processes that place primary responsibility for promoting efficiency in the hands of the agencies. As an accountability measure, NTIA requires that agencies justify their initial need for a frequency assignment and periodically review their continued need for the assignment, generally every 5 years. Officials from several federal agencies told us that they have been unable to complete the required 5-year reviews in a timely or in-depth manner because of shortages in experienced spectrum staff and competing agency priorities. Moreover, although NTIA has established monitoring programs to further increase agency accountability, it said that some of these programs are inactive because of staff and funding shortages. NTIA also conducts research and has technical initiatives under way to promote the efficient use of the spectrum. However, several agencies we reviewed reported difficulties implementing an important

71. *See* WIK-CONSULT REPORT, *supra* note 7, at 49 ("To continue to deliver greater economic and societal value per unit of spectrum over time, it is necessary to change the incentives faced by public sector spectrum users. There are a number of ways in which this could be done: [1] Limit the quantity of spectrum available to the public sector spectrum user so that they are motivated to invest in new technologies or to acquire spectrum in the same way as the non-public sector spectrum users to the extent that they need to support service growth and/or development; [2] Make the users publicly accountable for their spectrum use and for their associated technology choices; [3] Provide economic rewards/penalties for more or less efficient spectrum use."); PK REPORT, *supra* note 13, at 3 ("The President should require all agencies to prepare a "spectrum budget" in the same manner they prepare a federal budget, assessing existing and future needs. The NTIA would serve as coordinator for these agencies and would provide technical support, assisted by the federal Chief Technology Officer (CTO) and the Office of Management and Budget (OMB). Based on these exercises, the CTO, with support from the NTIA, would assist agencies in upgrading wireless equipment and enhancing the use of spectrum resources for individual agencies, in order to enhance their overall missions.").

> NTIA initiative for more efficient use of land mobile radio spectrum. Due to these workforce issues, we are recommending that the Department of Commerce conduct an analysis of the human capital needs of federal agencies for spectrum management as well as develop a strategy for enhancing its oversight of federal agencies' use of spectrum.[72]

Conceptually, reducing agency spectrum allocations to the "correct" level is attractive. Practically, however, implementing procedures that achieve this goal are daunting, and, as the excerpt above confirms, thus far unfruitful.

1. Treating Spectrum as an Asset

Yet additional evidence demonstrates the ineffectiveness of government action to improve efficiency of spectrum use. President Bush's Memorandum from 2004, echoed in Circular A-11 in 2011, directs agencies to treat spectrum as an economic asset, an order presumably necessary because the agencies have no inherent incentive to do so:

> [A]gencies should consider the economic value of radio spectrum used in major telecommunication, broadcast, radar, and similar systems when developing economic and budget justifications for procurement of these systems. . . . Spectrum should generally not be considered a free resource, but rather should be considered to have value and be included, to the extent practical, in economic analyses of alternative systems. In some cases greater investments in systems would reduce spectrum needs (e.g., purchase of radios that use less bandwidth than less expensive models); in other cases the desired service can be met with other forms of supply (e.g., private wireless services or use of land lines).[73]

The continued focus on government inefficiency suggests no action in this regard. In the most recent incarnation of this proposal—Circular A-11 in 2013—the OMB provides some general guidance on how an agency would undergo the valuation of its spectrum.[74] Still, such efforts are not independent of the agency using the spectrum, nor are they independent of the government. Absent independent verification, these valuations remain

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72. GAO-02-906, *supra* note 11, at 4.

73. OFFICE OF MGMT. & BUDGET, CIRCULAR NO. A-11, PREPARATION, SUBMISSION, AND EXECUTION OF THE BUDGET § 33.4 (Aug. 2011), *available at* http://www.whitehouse.gov/sites/default/files/omb/assets/a11_current_year/a_11_2011.pdf.

74. OFFICE OF MGMT. & BUDGET, CIRCULAR NO. A-11, PREPARATION, SUBMISSION, AND EXECUTION OF THE BUDGET § 31.12 (July 2013), *available at* http://www.whitehouse.gov/sites/default/files/omb/assets/a11_current_year/ a11_2013.pdf.

suspect. Indeed, the lack of incentives to respond properly to market prices is just as relevant to a proposal for agencies to treat spectrum as an economic asset.

2. A Failure in Accountability

Presumably, more rigorous accountability in spectrum use and management by federal agencies would require a complete picture of both the assignment and use of spectrum by such agencies. In the *1991 Spectrum Report*, the NTIA concluded:

> There is an absolute need for comprehensive data bases of spectrum use. . . . What is important is that the data should be correct, comprehensive and current.
>
> Based on the record compiled in the proceeding and our own experience in spectrum management, NTIA will investigate with the assistance of the FCC, the establishment of a common frequency assignment database, with compatible, modern file formats, to provide comprehensive information on spectrum use in the United States.[75]

Despite the obvious need for an accurate inventory of government spectrum and how it is used, in 2012—over twenty years later—the government had yet to produce a suitable database. As the GAO found:

> NTIA's data management system is antiquated and lacks internal controls to ensure the accuracy of agency-reported data, making it unclear if decisions about federal spectrum use are based on reliable data.[76]

Given the unabated inefficiency of spectrum use and management by the public sector, and the lack of incentives to remedy that inefficiency, history suggests that the prospects for much improvement in spectrum efficiency by federal agencies based on public oversight of spectrum use are minimal. Certainly, in some cases, a "gifted political executive" at a federal agency may be able to influence the efficiency of its programs and spectrum use.[77] However, such exceptions are no substitute for the systematic introduction of proper incentives.

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75. *1991 Spectrum Report*, *supra* note 18, at 30 (citing Comms. Satellite Corp. (COMSAT) Comments at 28–29).

76. GAO-11-352, *supra* note 11, at "Highlights".

77. *See, e.g.*, JAMES Q. WILSON, BUREAUCRACY 217 (1989).

C. Spectrum Currency as a Ghost Market Mechanism

In lieu of spectrum fees, the *PCAST Report* proposes to switch to an "artificial currency," referred to as "spectrum currency," rather than basing usage fees on actual dollars.[78] Spectrum currency is an intra-governmental spectrum accounting system that permits agencies to barter in spectrum without cash transactions.[79] The purposes of spectrum currency are as follows: First, spectrum currency provides a baseline of relative spectrum use (i.e., an inventory), and may, in conjunction with other mechanisms, aid in the measurement of actual spectrum use.[80] Second, spectrum currency may be viewed by an agency as an asset rather than a cash flow, thereby permitting longer-term planning and hopefully befuddling the counterproductive congressional budgeting process.[81] Third, establishing spectrum currency offers an "incentive" for agencies to migrate to network architectures that permit sharing.[82] This incentive system operates by empowering agencies to trade the *newly created* artificial currency for "real dollars" from the *newly created* Spectrum Efficiency Fund.[83] This proposal aims to create incentives for agencies to reduce their spectrum needs by eventually trading spectrum for capital investment dollars, thereby moving federal agencies toward a more efficient combination of spectrum and capital.

The combination of a spectrum currency and the Spectrum Efficiency Fund is appealing based on the simple logic illustrated in Figure 1. Federal agencies need some incentive, which they now lack, to select a more efficient combination of spectrum and capital—but to do so, the agencies need the wherewithal to trade spectrum for the necessary investment dollars. *PCAST* rejects a more direct market mechanism (spectrum fees) and, in its place, proposes a ghost market mechanism involving artificial currency and off-budget funding. In evaluating this approach, a critical question is whether such a pseudo-market mechanism provides federal agencies sufficient incentives to use spectrum in a manner that reflects "the true social cost of that use, which is measured in terms of other uses of the spectrum that are precluded by current federal use (the 'opportunity cost')."[84] The answer is almost surely "No."

Upon examination, the basic logic of spectrum currency is defective. Spectrum currency would be issued to agencies based on their existing

78. *See* PCAST REPORT, *supra* note 5, at 55.
79. *Id.* at 55–56.
80. *Id.* at 56. *See also id.* at 21–22 (proposing a new metric of spectrum use).
81. *Id.*
82. *Id.*
83. *See id.* at 57. The Spectrum Efficiency Fund is "the broadened and repurposed Spectrum Relocation Fund . . . . [This fund was] established by Congress in 2004 with the explicit and limited purpose of reimbursing agencies for the actual costs incurred in relocating Federal system auctioned bands." *Id.* at xv.
84. *Id.* at 55.

spectrum holdings.[85] Spectrum currency could be traded, perhaps for appropriations between agencies. So, for example, an agency with some unused or lightly used spectrum could "sell" it to another agency for cash, albeit indirectly. While PCAST believes that this "artificial currency" will not be appropriated by Congress in the same way as an outright cash sale,[86] this seems naïve; if spectrum currency is actually useful for anything, and can be converted to cash for purchases or otherwise impacts budgets, then Congress will likely react.

More significantly, this artificial currency model only allows federal agencies to participate in this pseudo-market, which exists solely "*within* the Federal Government."[87] No private transactions for spectrum currency occur. Thus, the final "price" obtained for such currency from inter-agency transactions cannot be reliably imputed as the *social cost* of spectrum use by government agencies because there is no reason to expect that an *intra*-governmental negotiated price for spectrum currency will be comparable to private, arms-length prices for spectrum involving transactions among public and private entities.[88] At the center of the spectrum problem is spectrum shortages in the private sector; yet, moving spectrum among federal agencies fails to address the core issue. Absent private sector participation, the private sector will continue to act as if spectrum is incredibly valuable and expensive, on net, while the government sector will continue to act as if it is cheaper than it really is.[89] Any potential gains will arise solely from a reallocation of spectrum among government users, rather than from a reallocation of spectrum between the private and public users. Consequently, this pseudo-market scheme will at best eliminate some inter-agency inefficiency within the federal government. While laudable, this approach does not address the problem of inadequate spectrum available to the private sector—the problem at the core of the Presidential Memorandum. Absent some mechanism by which the private sector can bid for the right to use the government's spectrum, no federal agency will base its decision on the "true social cost" of its spectrum. Spectrum currency is not a viable solution to the efficiency problem.

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85. *Id.* at xv.

86. *See generally id.* at 54–60 ("However, the introduction of spectrum fees would not necessarily remove or even significantly diminish the obstacles individual agencies face in trying to evolve their spectrum use in ways that would maximize efficiency by the Federal Government as a whole. In particular, an agency would legitimately fear that if it were to relinquish $500 million of spectrum use, and reduce its fee payment accordingly, it would later see its budget reduced by much of that $500 million and therefore see little or no benefit for its efforts. For that reason, we do not think a spectrum fee system is likely to be an effective way to promote Federal efficiency in spectrum use.").

87. *Id.* at 55 (emphasis added).

88. Even if the initial valuation is based on "comparable private sector uses for which the market has already set a price," *id.* at xv, this assignment of market values as a starting point is immaterial if the spectrum currency can only be traded among federal agencies.

89. That is, the budget line will not have the same slope as B_0 and B_1 in Figure 1.

D. Other Options

Finally, one can imagine somewhat more sophisticated schemes for simultaneously charging agencies for spectrum and appropriating funds to cover such outlays. Some of these systems might be largely self-financing, while others may not. One could, for example, initially fund spectrum supplemental allocations at the level $P \cdot S_0$, and then reduce the level systematically over time in the hopes that such reductions might spur efficient adjustments.[90] Alternately, one could encourage reduced spectrum use by sharing the social gains with staff charged with increasing efficiency,[91] or by rewarding an agency with a portion of the proceeds from an auction or lease of its spectrum to the private sector.[92] Other proposals include requiring public agencies to acquire spectrum at auction.[93] The number of permutations is probably infinite. It is undoubtedly desirable, however, to carefully investigate mechanisms that decentralize decision-making to those levels likely to possess the requisite knowledge and experience do a credible job of managing spectrum efficiently. Introducing incentives for efficiency is always difficult in the public sphere; as we have shown, the intrinsic lack of proper incentives could render the "market" approaches ineffective.

V. GOVERNMENT INEFFICIENCY AND SPECTRUM ALLOCATION BETWEEN PUBLIC AND PRIVATE USERS

As noted above, most agree that the government uses spectrum inefficiently.[94] But inefficient use by federal users is not the only problem; as noted by the *PCAST Report*, the "[f]ederal system as a whole" does not have the incentives to improve efficiency.[95] The GAO points to the "limited progress toward improved spectrum management."[96] Thus, inefficiencies exist in both use *and* management.[97] Inefficiency is systemic

90. This approach would operate much like price cap regulation, whereby price declines over time based on an efficiency factor and thereby encourages increases in the efficiency of production.

91. *See* ROBERT KLITGAARD & PAUL C. LIGHT, HIGH-PERFORMANCE GOVERNMENT: STRUCTURE, LEADERSHIP, INCENTIVES (2005), *available at* http://rand.org/content/dam/rand/pubs/monographs/2005/RAND_MG256.pdf.

92. *See* Federal Spectrum Incentive Act of 2013, H.R. 3674, 113th Cong. (2013), *available at* http://docs.house.gov/meetings/IF/IF00/20131210/101595/BILLS-1133674ih-HR3674FederalSpectrumIncentiveActof2013.pdf.

93. WIK-CONSULT REPORT, *supra* note 7, at 18.

94. *See* discussions *supra* Parts II & III.

95. PCAST REPORT, *supra* note 5, at ix; *see generally* WIK-CONSULT REPORT, *supra* note 7.

96. GAO-11-352, *supra* note 11, at 9.

97. The *WIK-Consult Report*, for example, points to problems with the government being both judge and jury in regard to its spectrum use. WIK-CONSULT REPORT, *supra* note 7, at 45 ("In some cases, the management of public spectrum is delegated to sectoral bodies (who are sometimes the spectrum user). A problem that this can lead to is that the manager

in government. As the nation's leading authority on public administration, Professor James Q. Wilson, observed:

> Government bureaus are less likely than private agencies to operate efficiently, at least with respect to the main goal of the organization. There are three reasons for this. First, government executives are less able than their private counterparts to define an efficient course of action. The public officials must serve a variety of contextual goals as well as their main or active goal and they are given little guidance as to what might constitute an acceptable tradeoff among these goals. Second, public executives have weaker incentives than do private executives to find an efficient course of action. The former have no property rights in the agency; they are not, in the language of economists, "residual claimants" who can put into their own pockets the savings achieved by greater efficiency. Third, public executives have less authority than private ones to impose an efficient course of action. Legislatures usually refuse to give to agency managers the power to hire and fire or to raise and allocate funds. Therefore, when it is important that executives have the ability, authority, and incentive to act efficiently, government agencies will not perform as well as their private counterparts.[98]

Inefficient management is a significant concern, yet its implications have yet to be fully considered as regards spectrum policy reform. As we see it, *it is the inefficiency of government spectrum management, not government spectrum use, which is most problematic.* If a government agency uses office furniture or copy paper inefficiently, then the consequences of that inefficiency are largely limited to that agency.[99] The producers of office furniture and copy paper sell their wares to many customers, face significant competition and, as a result, tend to be efficient in their operations. The fact that the Pentagon pays $750 for a hammer does not mean a consumer cannot purchase one for $10 at the local hardware store. In contrast, *if the government is an inefficient manager of spectrum, then the consequences of the inefficiency are realized across the entire spectrum ecosystem.* Issues of "managerial efficiency," therefore, are far more significant than "use efficiency." In order to better design policy to deal with the problem of managerial inefficiency, we turn to a theoretical

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may seek to keep all of its allocation for its own use (rather than sharing/releasing spare spectrum for use by others), particularly if incentives to do otherwise are weak. It is essential to adopt institutional arrangements that separate *management* from *use*.") (emphasis added).

98. WILSON, *supra* note 77, at 349–50.

99. In a case where the government is a very large consumer of an industry, the inefficiency of the government's actions may have broader economic implications.

analysis of the spectrum allocation decision in the presence of an inefficient government.

A. Formal Economic Model of Spectrum Allocation Between Private and Public Sectors

Our formal analysis of the best ways to repurpose government-held spectrum utilizes a simple general equilibrium ("GE") framework. A GE framework seeks to explain the supply side, demand side, and resulting prices in the whole economy, rather than focusing narrowly on a single market.[100] We believe such an approach is necessary because the problem of transferring spectrum rights from public to private hands is intimately entangled with government provision of public goods that require spectrum, such as national defense and public finance.[101] The discipline imposed by the GE setup forces one to account for *all* the effects of any proposed policy change within the context of the model. Even in the cases of those effects that are not explicitly included in the model, the GE approach serves to highlight exactly what such additional complications imply. Still, the model is an abstraction, and in the present case, where some agents are considered to be "inefficient" actors (i.e., the government), we must specify a particular form of inefficiency. Our chosen strategy is to impose a very specific and limited form of inefficiency on the government, and to otherwise give the government the benefit of doubt by assuming its motivations are pure and its operations are efficient within its own sphere. As will be apparent, relaxing these assumptions only strengthens our recommendations.

First, regardless of its chosen approach to spectrum policy, we return to the widespread recognition that that the U.S. government is an inefficient manager of spectrum resources. This observation is, in fact, the primary motivation for spectrum reform. However, one virtue of the analysis to follow is that we can show that this assumption of government inefficiency is actually *stronger* than is necessary to reach fairly concise policy recommendations. In fact, we assume in what follows only that the government is a *less* efficient manager of spectrum resources *used privately to produce private goods* than are the private producers

100. *See* Kenneth J. Arrow & George Debreu, *The Existence of an Equilibrium for a Competitive Economy*, 22 ECONOMETRICA 265–90 (1954).

101. In this way our model is consistent with the approach outlined in the *WIK-Consult Report*. *See* WIK-CONSULT REPORT, *supra* note 7, at 1 ("*Economic efficiency* is clearly important, but it cannot be the only measure of success—the allocation mechanisms must support demanding public sector applications, many of which are essential to the protection of life and property. We choose instead to refer to our central objective in the study as one of optimising *socioeconomic efficiency*. We do so with an eye to a distinction that many in the field draw between the *efficiency* and the *effectiveness* of spectrum allocation in the public sector, where effectiveness refers not only to productive efficiency (see below) but also to being *fit for purpose* in the sense of enabling the public sector spectrum user to properly perform its mission.").

themselves. In other words, *it is not necessary to say that government is inherently inefficient, but only that it is inherently inefficient to have the government manage the resources used privately by others.* This inefficiency can be thought of as an additional cost arising from the mixed nature of the property rights involved.

Second, it seems likely that any reform in spectrum policy could entail both the government auctioning its spectrum and government leasing of spectrum to private users. Many of the proposals for spectrum reform include these options,[102] both of which will presumably provide revenue to the government, either in the form of spectrum auctions or spectrum usage fees.[103] For reasons of realism, we imagine that decisions regarding spectrum auctions will be known prior to leasing decisions—that is, a certain amount of spectrum is already allocated to private licensees. Further, we assume that the government acts to maximize social welfare in its leasing behavior. Our findings explicitly assume that government behavior is consistent with the public good.

Third, our model incorporates a basic assumption about the irreducible role of public agencies: consumers derive benefits from consumption of both a private good, produced using spectrum resources, and a public good, which is only created through government production. Certainly, the government provides valuable services using its spectrum allocations. As such, positive amounts of both public and private goods will characterize our equilibrium outcomes.

Fourth, we emphasize and maintain the distinction, which has often been lost in debates over public spectrum, between spectrum leased by the government—over which public control or management is maintained—and spectrum used in sharing arrangements. The question of how spectrum can or should be shared among competing users is logically distinct from the question whether such uses require public management of the spectrum resource. This latter claim—that sharing will happen only under public management—amounts to assuming that the government has some talent or ability unavailable to anyone else. This is an implausible conjecture, to say the least, and one not obviously in line with the basic conclusion of most prior research: government lacks proper incentives to manage spectrum efficiently.[104]

Therefore, in the analysis that follows, one should keep in mind that leased spectrum refers only to previously government-owned spectrum that is made available to private users for private purposes in exchange for a fee, which is essentially the *PCAST Report*'s approach to spectrum

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102. PCAST REPORT, *supra* note 5, at 12 ("This report argues that the United States should shift to a spectrum management model that makes possible a continual stream of revenue instead of one-time auction returns. The revenues would derive from wireless services eager to pay modest fees under a variety of leasing arrangements to obtain spectrum access with varying levels of quality of service and lease lengths, appropriate to their business needs.").

103. *Id.*

104. *See* discussion *supra* Part III.

management. Such leased spectrum may or may not be shared among users, just as spectrum held under conventional exclusive licenses may or may not be shared.[105] The key point is that such spectrum is *encumbered*, i.e., a public authority controls and manages it. Such publicly managed spectrum might be shared among several private users, or it might be utilized by only one user. We will return to the issue of spectrum sharing below.

Finally, we assume throughout that price and quantity expectations of market agents are correct: none of the results arises due to any misapprehension over prices, quantities, or the preferences or behavior of other actors.

Given these relatively straightforward assumptions, as a general matter, *we come to the conclusion that it is preferable for the government to sell spectrum rather than lease it.* In equilibrium, leased spectrum earns lower returns and is less effective in production of the private good. One can, in fact, use these results to formulate a "hypothetical test" for the efficiency of any spectrum reform proposal:

> If a proposal envisions leasing spectrum under government management, then either that proposal contains insufficient levels of spectrum auctions or the government management of the spectrum must be necessary to realize its benefits.

In general, then, government management of spectrum used by private agents should be *de minimis*, except in cases wherein one can offer a compelling case for government intrusion.

To formalize the argument, suppose the government initially has a block of spectrum denoted *S*. This spectrum will be used in three ways. First, some quantity s_0 can be sold at a competitive market price r_0 to private users, who will then use it to produce private goods. Second, with all agents having full knowledge of s_0, an additional quantity s_1 can be "leased" to private firms for the production of private goods at a competitive market rent r_1. (This "leasing" model includes forms of spectrum sharing that employ a usage fee, and encompasses any regime in which the government is the active manager of spectrum resource.) Finally, the remaining public spectrum s_g, $s_g = S - s_0 - s_1$, is efficiently used by the government to produce a public good of benefit to all. To summarize the key variables of the model, we have as follows:

105. PCAST REPORT, *supra* note 5, at 43 ("Long-term Licensing would be very similar to current licensing in bands such as those used for personal communications services (PCS) or AWS, where the licensee gets a multi-year (10–15 years) initial assignment. Currently, in the United States, such assignments also have an expectancy of renewal, increasing the value of the initial assignment. Rights for such assignments could be exclusive, or could include well-defined easements for secondary uses, such as low-power unlicensed or pre-emption for public safety use.").

S: total spectrum;
s_0: spectrum sold to the private sector in the form of exclusive licenses;
s_1: spectrum leased to the private sector by the government-manager; and
s_g: spectrum used by the government to provide public services [$= S - s_0 - s_1$].

The strategic scenario is as follows. First, an un-modeled political process will determine the quantity s_0. Then, given this quantity, the government agency holding the remaining public spectrum will select a quantity s_1 to be leased. We assume s_1 is selected to maximize social welfare, which is given as the welfare of a representative household. Finally, both private and public goods are produced using spectrum inputs and labor. Households receive transfers from the government funded by proceeds from spectrum auctions (labeled t). Households also receive labor income. Private firms are competitive price takers who produce private goods using technologies that exhibit constant returns to scale. Prices in the model are r_0, the price of a unit of s sold under exclusive license, r_1, the leasing (encumbered) price of a unit of spectrum, and w, the wage rate.

Private firms produce only private goods, and are assumed to do so under the usual Cobb-Douglas linear homogenous production function:

$$y = f(s, L) = As^{\alpha}L^{(1-\alpha)} \tag{1}$$

where y is output of the private good, A is a productivity factor, and α represents the degree of substitution between spectrum and labor in production.

As described above, it is assumed that spectrum leased under government control, s_1, is at least marginally less effective than is spectrum transferred to private hands. To capture this effect, we assume that "effective spectrum" in private production s_p is given by the equation: $s_p = s_0 + \lambda s_1$, where $0 < \lambda < 1$.[106] Thus, the factor lambda (λ) captures this inefficiency inherent in government spectrum management (in the production of private goods).

As firms produce private goods under the Cobb-Douglas linear homogenous production function, they buy and lease spectrum for this purpose, and hire employees as well. They maximize their profits to determine their demands for factors:

$$\underset{s_0, s_1, L}{Max}\{A(s_0 + \lambda s_1)^{\alpha}L^{(1-\alpha)} - r_0 s_0 - r_1 s_1 - wL\} \tag{2}$$

106. Say the private sector has 100 MHz in exclusive licensees (s_0) and that the government makes 80 MHz available for lease (s_1). If $\lambda = 0.5$, then the effective amount of spectrum available to produce private sector output is 140 MHz [$= 100 + 0.5 \cdot 80$].

As is usual in models of this type, in equilibrium prices for factors equal their marginal products. If we let MPS and MPL denote the marginal physical products of unencumbered spectrum and labor, respectively, then we obtain the competitive prices:

$$r_0^* = \text{MPS}, \quad r_1^* = \lambda \text{MPS}, \quad w^* = \text{MPL} \tag{3}$$

Here, leased spectrum sells for a lower price, reflecting its diminished usefulness compared to s_0. Due to the assumption of constant returns, the firms have zero excess profit in equilibrium so we need not specify firm ownership.

Consumers appear in the model in the usual guise of the "representative household," and they obtain utility from the consumption of both the private good (their consumption is denoted by c) and the public good, which is only produced by the government. For simplicity, suppose the public good is produced using only spectrum (this is of no consequence to the conclusions). Suppose output of the public good is just $\theta \ln(s_g)$, where θ is a known positive parameter. Then specify consumer utility U as:

$$U = \ln(c) + \theta \ln(s_g) \tag{4}$$

The simple additive, logarithmic form of U is adopted purely for convenience: the log specification assures us that the optimal plan will always involve production of both private and public goods.

The consumer solves the optimization problem:

$$\max_{c,L} = \{\ln(c) + \theta \ln(s_g)\}, \tag{5}$$

subject to the budget constraint:

$$c = wL + t, \tag{6}$$

where L is household labor supplied and t is any net transfers of government benefits to the private sector. Again, for simplicity, our specification of consumer utility does not include leisure. This implies that labor will be inelastically supplied at all wage rates. In accordance with convention, we will assume that labor supply must satisfy $0 \leq L \leq 1$, so that in equilibrium $L^* = 1$.

In keeping with our description of the strategic environment above, we assume that, once s_0 (spectrum sold initially) is known, the relevant government authority then selects the amount of spectrum to lease, s_1 and thus the amount to retain for public good uses, s_g, in order to maximize the welfare of society. In this model, that means these values are selected to

maximize household utility U, recognizing that $c = w^* + t$, $s_g = S - s_0 - s_1$, and $t = r_0^* \cdot s_0 + r_1^* \cdot s_1$. In "closing the model," we specify that any income obtained by the government through spectrum auctions or leasing is costlessly transferred to the private sector as a benefit. Thus, the household consumes goods equal to its direct income $w^* + t$, and consumes that amount of the public good provided by the government using retained spectrum s_g.

Before illustrating the model solutions graphically, we find their explicit expressions. All choice and "state" variables are functions of s_0. Thus, the way in which the performance of the economy varies with the amount of spectrum put under private management can be found directly. The government authority, viewing s_0 and then selecting s_1 (leased spectrum) to maximize social welfare, will optimize its selection of leased spectrum according to the condition:

$$s_1^* = (\theta/(\alpha+\theta))S - (\alpha + (\theta/\lambda))(\alpha+\theta)^{-1} s_0 . \quad (7)$$

Equilibrium government spectrum is thus:

$$s_g^* = (\theta/(\alpha+\theta))[S + (\lambda^{-1} - 1)s_0]. \quad (8)$$

These expressions immediately allow us to conclude that $\partial s_g^* / \partial s_0 > 0$ and $\partial s_p^* / \partial s_0 > 0$. In other words, the amount of spectrum available for public use and the amount made available for private use both rise when more spectrum resources are initially in private hands. This occurs because of the differential efficiency in the application of spectrum to private production under "auction" and "lease." These results, in turn, directly imply that:

$$\partial y^* / \partial s_0 > 0 ; \quad (9)$$

$$\partial w^* / \partial s_0 > 0 ; \quad (10)$$

$$\partial t^* / \partial s_0 > 0 ; \text{ and} \quad (11)$$

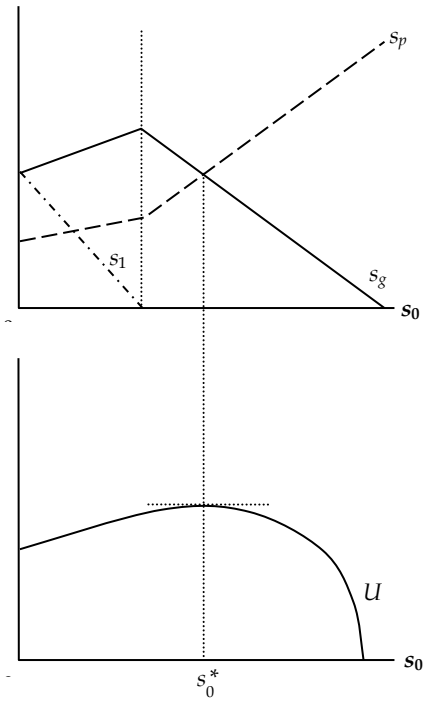
$$\partial U^* / \partial s_0 > 0 . \quad (12)$$

These conditions state that equilibrium consumption (y^*), wages (w^*), Government benefit transfers (t^*), and social welfare (U^*) keep rising as s_0 (exclusively-licensed spectrum) increases whenever $s_1^* > 0$.

The following figure illustrates this for some simple parameter values ($\theta = \alpha = \lambda = 0.5$, $S = 100$, and $A = 10$). In the top panel of Figure 2 below, private spectrum s_0 is measured on the horizontal axes, and the variables s_p, s_g, and w are measured on the vertical axis. In the bottom panel, household utility is plotted against s_0. As shown in the figure and discussed above, the amount of spectrum available for public use (s_g) and

the amount made available for private use (s_p) both rise when more spectrum resources (i.e., effective spectrum) are initially in private hands. Also, once s_1^* corners at zero (i.e., no leasing of spectrum to the private sector), household utility (welfare) will continue to rise as s_0 increases until a socially optimal balance between private and government spectrum is achieved.

Figure 2. Spectrum Allocation



The figure summarizes several strong conclusions. First, the government, given its *relative* inefficiency, should not be leasing spectrum to the private sector, as a positive value of s_1 is not optimal. The result has a useful practical implication for policymaking: any spectrum plan involving the government leasing spectrum to the private sector (e.g., the *PCAST* proposal)[107] implies *the government is not auctioning enough spectrum under standard exclusive licenses.* Total social welfare and public good supply are each higher when more spectrum is sold without encumbrance, up to that point at which retained government spectrum is just sufficient to produce public goods at a socially optimal level.[108]

107. See PCAST REPORT, *supra* note 5, at 42–47.
108. Recall that, by assumption, spectrum alone is used to produce public goods.

Likewise, wages rise as more spectrum is repositioned into private hands when the goal is to produce private goods with it. This is not really a surprise: if government is a bad spectrum *manager*, then it should not *manage* spectrum.

An important subtlety is attached to these conclusions. To say that the government should not manage spectrum—but should auction licenses in the usual way—does not imply anything in particular about the usefulness of sharing spectrum. These are quite different matters. It often seems that arguments for sharing frequencies envision some public authority as a manager and, in the absence of this public manager, sharing is precluded. It is not. The private sector regularly shares spectrum.[109] Yet, even if public sector management was required, the admitted weakness of the government in managing spectrum implies that forgoing sharing might be justified to avoid the inefficiency of government management. If the government is a very poor manager, then one would be forced to compare a poorly managed sharing regime with a well-managed private sharing regime where, by assumption, some forms of sharing are impractical.

Additionally, the GE character of the model allows us to reason more precisely about the issue of leasing or sharing government-managed spectrum versus auction of exclusive licenses. Obviously, we impose the assumption that s_1 is less productive than s_0 in the private sector. This assumption is fairly plausible from prices observed for restricted licenses.[110] However, in a market setting, such managed spectrum (s_1) will likewise sell at a lower cost. Thus, at first glance, one cannot immediately see whether such restrictions would harm the economy: after all, though this spectrum is a bit less desirable, the price is also lower and, in equilibrium, a firm should be indifferent between these two modes of producing the marginal unit. All of this is true. It is also beside the point, as the analysis clearly demonstrates. The lower price available to firms for poorer spectrum translates into lower transfers and consumption from the public itself. When the entire economy is encapsulated, it becomes apparent that such restrictions, in the absence of a suitably large countervailing benefit, are counterproductive if the goal is maximizing social welfare, wages, and so forth.

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109. For details on such sharing, see FCC, *Spectrum Leasing* (last updated July 8, 2010), http://wireless.fcc.gov/licensing/index.htm?job=spectrum_leasing#d36e70 (including, *inter alia*, sublease and private commons arrangements).

110. George S. Ford, Thomas M. Koutsky & Lawrence J. Spiwak, *Using Auction Results to Forecast the Impact of Wireless Carterfone Regulation on Wireless Networks*, PHX. CTR. POL'Y BULL. NO. 20 (2d ed. May 2008), *available at* http://www.phoenix-center.org/PolicyBulletin/PCPB20Final2ndEdition.pdf; KENT R. NILSSON, OFFICE OF INSPECTOR GEN., OFFICIAL REPORT: D BLOCK INVESTIGATION (Apr. 25, 2008), *available at* http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-281791A1.pdf.

B. Market Management of All Spectrum

In our model, we have assumed that the government is a relatively inefficient manager of spectrum used by private parties, which implies that the government should not manage the private sector's spectrum under a leasing or arrangement. We assumed also that the government managed its own spectrum and did not lease it from the private sector or any other entity other than itself. If the government is an inefficient manager of its own spectrum—and it appears that it is—then it may make sense for the government to divest itself of its entire spectrum holdings and subsequently lease back what it needs from the private sector. A similar proposal was made in the *1991 Spectrum Report*, which suggested:

> [F]ederal users could have a private contractor build and operate a "pooled" system using government spectrum to meet existing federal needs. As an incentive to operate most efficiently, the contractor could sell to the public any excess capacity on its system once federal needs were met as its first priority.[111]

While the proposal was undeveloped in the *Report*, the idea warrants further investigation. Certainly, though, there may well be reasons to allow government agencies to manage spectrum used in production of public goods, much as private firms should manage resources used in private production. Yet, it is widely accepted that the public sector has only weak incentives, if any, for efficient use, but the private sector has a powerful motive for efficiency: profit maximization.

Our model can be modified to consider this policy option. In the lower panel of Figure 2 above, we assume that s_1 must be non-negative, i.e. the government holds its own spectrum, and this creates a maximum in U. If we permit s_1 to be negative, and do not assume that the government is a better manager of public spectrum than the private sector, then household utility (U) rises as s_0 increases across the entire range of s_0. In other words, all spectrum should be sold to the private sector.

It is perhaps reasonable, then, to inject the proper incentives into the public sector's use of spectrum through private sector management. As observed in the *1991 Spectrum Report*:

> We also recognize, however, that despite its advantages, there are real practical issues involved in designing and

111. *1991 Spectrum Report*, *supra* note 18. This is different than proposals to have all private sector spectrum returned to the government for shared use. *See, e.g.*, Jeff Kagan, *The FCC's Wireless Spectrum Band-Aid*, E-COMMERCE TIMES (Oct. 4, 2012), http://www.ecommercetimes.com/story/76312.html. The NTIA proposed a government spectrum "pool" that was managed by a private sector entity, thereby embedding in the management the incentive for efficiency that the government lacks. *Id.*

> implementing a market-based system for spectrum management. . . . Nevertheless, we believe that the public interest would be better served if spectrum management in the United States made greater use of the "management" approach relied on so successfully throughout our economy to allocate resources and produce those goods and services most valued by consumers—the market system.[112]

As our theoretical model shows, and as the NTIA has previously concluded, the discussion of efficient use must not be limited to spectrum *use*, but also to spectrum *management*. If, as the *PCAST Report* concludes, the "[f]ederal system as a whole" does not have the incentives to improve efficiency,[113] then a shift to private sector management of spectrum is the proper direction for the continued spectrum reform effort.

C. Caveats

As with any abstract analysis, the model presented here can be criticized on several fronts. Some of these criticisms—such as complaints over the log linear form of household utility or the inelasticity of labor supply—are unimportant because the basic findings of the model do not depend on these simplifying assumptions. In many respects, the model form applied here is extremely standard and familiar in theoretical economics. However, the key assumption—that the government is a poorer manager of spectrum used to produce private goods than are private producers themselves—deserves careful examination.

Despite its admission that the federal government is an inefficient user and manager of spectrum, one of the signature proposals of the *PCAST Report* patently rejects any further spectrum clearing and auctioning in favor of "sharing" or "leasing" spectrum currently licensed to government users.[114] Other proposals call for an expanded role for the government in spectrum management, though typically to a lesser extent than the *PCAST Report*. Such plans are rather difficult to reconcile with the notion that the government is a bad manager of spectrum. In order to rationalize such plans, some cases must exist in which government management of some spectrum is, in fact, more efficient than private management. Further, these "special cases" seem to coincide with opportunities for spectrum sharing that are not available to the private sector.

There are two obvious possible explanations for these "special cases." First, it might be believed that placing additional spectrum in private hands will lead to monopoly, or prevent the dissolution of a monopoly. In terms of the model, such fears suggest that λ might be

112. *1991 Spectrum Report*, *supra* note 18, § II.A.1.a.
113. *See* PCAST REPORT, *supra* note 5, at ix.
114. *See id.* at 10.

greater than one in some cases. There are several plain defects in this reasoning. First, even if private use results in monopoly, we are faced with a comparison between a private monopoly outcome and an inefficient government outcome. Most studies on the topic conclude that the government is inefficient, whereas there is considerable debate over whether spectrum auctions will lead to monopoly. Private use of spectrum need not be socially perfect to be better than inefficient public use. Further, the government may have better means to promote competitive industry structures, such as the antitrust laws or regulation, so monopoly need not arise.

There are other concerns with using the government's management of spectrum to influence market structure. If, for example, one firm had lower costs than any other, it might take over the entire market. One could prevent this by making this firm's costs higher by limiting its access to an input (e.g., spectrum) to levels far below those required by cost minimization, thus forcing the firm to produce inefficiently. Such a plan would not necessarily improve outcomes, as this scheme merely trades off high prices from monopoly for high prices from inefficient production. Alternately, under spectrum exhaust—that is, where output cannot be increased economically by increasing the amount of capital applied to a fixed amount of spectrum—rationing spectrum via government management would lower prices only if monopoly power were *absent*. Competition does not increase output or lower prices if output levels are strictly constrained by a scarce input.[115] If a monopoly is producing at its production constraint given available inputs, there is no difference between monopoly and any other market form.

The second "special case," implicit in much of the *PCAST Report*'s discussion, is based on the idea that spectrum sharing requires a public authority with managerial power. Private firms are assumed to lack the ability and/or the incentives to implement spectrum management practices that would make socially beneficial sharing possible. The evidence against this proposition is compelling. The private sector today does a great deal of spectrum sharing in the form of secondary-market leases, whereas the government does scarcely any.[116] If anything, the evidence suggests it is

115. *See, e.g.*, T. Randolph Beard & David L. Kaserman, *Testing for Collusion During Periods of Input Supply Disruptions: The Case of Allocations*, 46 ANTITRUST BULL. 213, 219–21 (2000); T. Randolph Beard, George S. Ford, Lawrence J. Spiwak & Michael Stern, *Wireless Competition Under Spectrum Exhaust*, 65 FED. COMM. L.J. 79, 89 (2013); Luke Froeb, Steven Tschantz & Philip Crooke, *Bertrand Competition with Capacity Constraints: Mergers Among Parking Lots*, 113 J. OF ECONOMETRICS 49, 66 (2003); Arturs Kalnins, Luke Froeb & Steven Tschantz, *Mergers Increase Output When Firms Compete by Managing Revenue* (Vanderbilt Univ. Law Sch., Working Paper No. 10-27, 2010), *available at* http://ssrn.com/abstract=1670278.

116. For example, see the NTIA's recent endorsement of a spectrum sharing deal between the Department of Defense and the broadcast industry in the 2025–2100 MHz band, which will allow the eventual auction of the 1755–1780 MHz band for commercial mobile services. Phil Goldstein, *Pentagon Strikes Deal with Broadcasters, Clearing Way for 1755–1780 MHz Auction*, FIERCE WIRELESS (Nov. 26, 2013), http://www.fiercewireless.

the private sector, not the public sector, which can oversee the widespread sharing of spectrum.[117]

Finally, there may be cases where a federal agency requires a specific amount of spectrum to perform its duties, but its use of the spectrum is infrequent or irregular. The spectrum may be available for private sector users at certain times or locations, and in such cases, sharing by the government may be a sensible strategy to increase the productivity of spectrum. Yet we see very little sharing of this type, mainly because there is so little incentive for federal users to bother with it. We do not discourage sharing or efforts to create incentives to share, because such spectrum may be unavailable to the private sector under any other arrangement. Nevertheless, even under a sharing paradigm, the government's management of spectrum should be the exception, not the rule.

VI. CONCLUSION

With ever-increasing demands on the nation's spectrum resources by both the public and private sectors, it is imperative that policymakers implement policies that produce the right incentives for the efficient use of spectrum. Perhaps the most important contemporary spectrum policy issue is how to use federal spectrum more efficiently, thereby freeing up spectrum resources for use by the spectrum-constrained commercial sector. Much of the prior work on this topic has focused on the public sector's inefficient use of spectrum, and most studies propose the imposition of market or quasi-market mechanisms on federal users to improve incentives. We summarize the basic economic model of production upon which the existing literature rests, and conclude that while the proposals to improve efficiency may offer some benefits, the "market" approaches may not, in the long-term, do much to enhance efficiency.

We take the question of efficiency in the government's management of spectrum to be a more significant concern than is the government's use of spectrum. Using the inefficiency of government management as a starting point, we consider the implications within a simple, standard general equilibrium model of the economy with both public and private goods. Even when the government is assumed to be wholly rational, benevolent, and efficient—given its constraints—we show that government management of spectrum resources is not desirable beyond some minimum

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com/story/pentagon-strikes-deal-broadcasters-clearing-way-1755-1780-mhz-auction/2013-11-26.

117. *But cf.* Werbach & Mehta, *supra* note 10, at 137 ("Spectrum sharing . . . has significant benefits that have not been fully included in the policy calculus. Especially when considering the importance of spectrum for innovation, new businesses, free expression, and civic benefit, sharing mechanisms deserve at least as much emphasis as spectrum clearing. The burden of proof [for new spectrum allocation] should be on proponents of clearing to show that the benefits of greater exclusivity outweigh those of expanded sharing.").

level: the government should control only however much spectrum it requires to perform its duties. Again, if the government is a bad manager of spectrum, then it should not manage spectrum. Furthermore, any proposals that contemplate leasing government–managed spectrum to private parties for private use *may be presumed* to auction too little spectrum for exclusive licensed use. Also, if the government is not good even at the management of spectrum utilized for public purposes, then the government should divest itself of spectrum through auctions and lease spectrum it needs, in the same manner in which it buys almost everything else it uses. Such a proposal was made over twenty-years ago by the NTIA.

In sum, there is generally nothing about radiofrequency spectrum that makes it so utterly unlike any other good so as to necessitate unique, speculative, and grossly bureaucratic methods of allocation and management. Everyone wishes government were efficient. Realists, though, do not look to government programs to make this happen. The reform of government spectrum should involve a substantial shift of the nation's scarce spectrum resources to the management of the private sector.