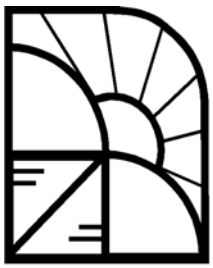

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Phoenix Center Policy Paper Number 46:

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

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Phoenix Center Policy Paper No. 46
Market Mechanisms and the Efficient Use and Management of Scarce Spectrum Resources

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Abstract: Today, the Federal Government has assignments for about half of what is considered to be "beachfront" spectrum. However, most agree that Government agencies, and the Government as a whole, use and manage spectrum resources inefficiently. As such, much attention is now focused on improving the Federal Government's efficiency in the use and management of its spectrum resources with the aim of freeing up spectrum which can be repurposed for the spectrum-constrained commercial sector. In this PAPER, we first tackle Government spectrum use and demonstrate that the "ghost market" approaches commonly proposed to enhance public sector efficiency in spectrum such as a General Services Administration-type model to the recent spectrum sharing proposal by the President's Council of Advisors on Science and Technology use may not, in the long-term, be effective. Next, we turn to Government spectrum management and present a general equilibrium model addressing spectrum assignment between public and private users using either auctions or leasing. We find that Government management of spectrum resources is not desirable beyond some minimum level. In fact, any proposal that contemplates the leasing of Government–managed spectrum to the private sector may be presumed to include "too little" auctioning of Government spectrum to the private sector in the form of exclusive licenses. We conclude that if the goal of spectrum use and management is economic efficiency, then policymakers should expand the private sector's management of the nation's scarce spectrum resources.

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TABLE OF CONTENTS:

I. Introduction

In light of the rapid growth of demand for data transmission on mobile wireless networks, the *National Broadband Plan* proposed to increase the amount of spectrum available for commercial use by 500 MHz by 2020, with 300 MHz of this additional spectrum specifically allocated for mobile broadband use by 2015.[1] The *National Broadband Plan's* proposal seeks to increase significantly the amount of spectrum presently used for mobile communications service in the hopes of postponing the effects of spectrum exhaust in the U.S. mobile wireless

[1] CONNECTING AMERICA: THE NATIONAL BROADBAND PLAN, Federal Communications Commission (March 16, 2010) (available at: http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-296935A1.pdf) (hereinafter the *National Broadband Plan*) at Ch. 5.

industry.[2] Given the near total absence of fallow spectrum in 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]

While it is acknowledged that Federal agencies need spectrum to carry out their mission-critical duties such as national defense and homeland security, it is also acknowledged that public-sector users have very weak incentives (if any) to use their spectrum efficiently. As one recent government-sponsored study concludes, "Federal 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. Thus, improving spectral efficiency by the public sector

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

3 *See, e.g.,* T.R. Beard, G.S. Ford, L.J. Spiwak, and M. Stern, *Taxation by Condition: Spectrum Repurposing at the FCC and the Prolonging of Spectrum Exhaust,* PHOENIX CENTER POLICY PAPER NO. 44 (September 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* n. 1 at 84-5.

5 REPORT TO THE PRESIDENT: REALIZING THE FULL POTENTIAL OF GOVERNMENT-HELD SPECTRUM TO SPUR ECONOMIC GROWTH, Executive Office of the President - President's Council of Advisors on Science and Technology (July 2012) (available at: http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast_spectrum_report_final_july_20_2012.pdf) (hereinafter *"PCAST Report"*), at p. 8; *see also* A. Pai, *Too Much Government, Too Little Spectrum*, Member Diary, REDSTATE (January 3, 2013) (available at: http://www.redstate.com/ajitpai/2013/01/03/too-much-government-too-little-spectrum/); J. Gruenwald, *Wireless Industry Already Looking Ahead for More Spectrum*, NATIONAL JOURNAL, TECHNOLOGY (February 29, 2012) (available at: http://www.nationaljournal.com/tech/wireless-industry-already-looking-ahead-for-more-spectrum-20120229) (quoting Charla Rath, Vice President 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 …").

6 *PCAST Report, id.* at p. ix.

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 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 PAPER 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 this same conceptual framework, prior studies, including those conducted by 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 pseudo-market price, for the spectrum they use. Given our analysis, we are skeptical that such proposals—especially those calling for internal spectrum "markets" within the Government—will ultimately lead to significant or long-term improvements in the public sector's efficiency in using their spectrum.

Second, we detail a theory of spectrum allocation across public and private users. In this model, we are not concerned with ways with which to improve the public sector's efficiency in its *use* of spectrum, but rather address the key question about 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 options: (i) Federal spectrum holdings continue to be managed by the Government and leased to private-sector users; and (ii) Federal spectrum holdings are auctioned to and managed by the private-sector for commercial uses. Our model provides a

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[7] *See, e.g.,* J. S. Marcus, J. Burns, F. Pujol, P. Marks, and R. Caves, *Optimising the Public Sector's Use of the Radio Spectrum in the European Union*, *WIK-Consult Report* (October 27, 2008) (available at: http://www.wik.org/index.php?id=493&L=1) (hereinafter "*WIK-Consult Report*") at p. 40; *Final RSPG Opinion: Request by the European Commission to the Radio Spectrum Policy Group for an Opinion on Best Practices Regarding the Use of Spectrum by Some Public Sectors*, European Commission, RSPG09-258 (February 2009) (available at: https://circabc.europa.eu/sd/d/800fed58-e09e-4dec-85b3-ecf0ea8cd2aa/RSPG12-411%203rd%20Progress%20Report%20RSPG%20WG%20Spectrum.pdf) (hereinafter "*EU Best Practices*"). *See also* K.R. Carter and J. S. Marcus, *Improving the Effectiveness and Efficiency of Spectrum Use by the Public Sector: Lessons from Europe*, Unpublished Manuscript (2009) (available at: http://ssrn.com/abstract=1488852).

number of policy-relevant findings. Among the more important of these findings, we show that, when all economic consequences are considered, the leasing of spectrum *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 Government to produce public goods should be sold to the private sector and leased back for the provision of public goods (in much the same way as it buys other inputs). Put bluntly, if the Government is demonstrably incapable of managing and using spectrum resources with efficiency in mind—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 economic efficiency, then policymakers should expand the private sector's management of the nation's scarce spectrum resources, including possibly the management of spectrum used by Federal agencies.

To be clear up front, we offer no specific mechanisms by which to improve public sector efficiency or 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 which 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 the expansion of private-sector management of the nation's scarce spectrum resources.

II. Background

A heightened attention to Government spectrum reform was stimulated by the *National Broadband Plan*'s call for an additional 500 MHz of spectrum for commercial use, some of which is expected to come from the repurposing of Federal assignments. Subsequent to the *Plan's* release, 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

[8] PRESIDENTIAL MEMORANDUM: UNLEASHING THE WIRELESS BROADBAND REVOLUTION, The White House (June 28, 2010) (available at: http://www.whitehouse.gov/the-press-office/presidential-memorandum-unleashing-wireless-broadband-revolution).

to help meet this goal.[9] There has also been a report released on the topic by the President's Council of Advisors on Science and Technology ("PCAST"), which calls for, among other things, the total 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 mostly 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

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[9] *Plan and Timetable to Make Available 500 Megahertz of Spectrum for Wireless Broadband,* NTIA (October 2010) (available at: http://www.ntia.doc.gov/files/ntia/publications/tenyearplan_11152010.pdf); *An Assessment of the Viability of Accommodating Wireless Broadband in the 1755 – 1850 MHz Band,* NTIA (March 2012) (available at: http://www.ntia.doc.gov/files/ntia/publications/ntia_1755_1850_mhz_report_march2012.pdf) As discussed *infra*, these documents by no means exhaust the government's coverage of this issue prior to the release of the *National Broadband Plan*.

[10] *PCAST Report, supra* n. 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.")

[11] *See, e.g., Spectrum Management: NTIA Planning Processes Need Strengthening to Promote Efficient Use of Spectrum by Federal Agencies*, Government Accountability Office, GAO-11-352 (April 2012) (available at: http://www.gao.gov/new.items/d11352.pdf); *Spectrum Management: Federal Government's Use of Spectrum and Preliminary Information on Spectrum Sharing*, Government Accountability Office, GAO-12-1018T (September 2012) (available at: http://www.gao.gov/assets/650/648206.pdf); *Spectrum Management: Federal Relocation Costs and Auction Revenues*, Government Accountability Office, GAO-13-472 (May 2012)(available at: http://www.gao.gov/assets/660/654794.pdf); *Telecommunications: Options for and Barriers to Spectrum Reform*, Government Accountability Office, GAO-06-526T (March 2006)(available at: http://gao.gov/assets/120/113012.pdf); *Telecommunications: Strong Support for Extending FCC's Auction Authority Exists, but Little Agreement on Other Options to Improve Efficient Use of Spectrum*, Government Accountability Office, GAO-06-236 (December 2005); *Spectrum Management: Better Knowledge Needed to Take Advantage of Technologies That May Improve Spectrum Efficiency,* Government Accountability Office, GAO-04-666 (May 2004) (available at: http://www.gao.gov/new.items/d04666.pdf); *Interdepartment Radio Advisory Committee: IRAC Representatives Effectively Coordinate Federal Spectrum but Lack Seniority to Advise on Contentious Policy Issues*, Government Accountability Office, GAO-04-1028 (September 2004) (available at: http://gao.gov/assets/250/244315.pdf); *Telecommunications: Better Coordination and Enhanced Accountability Needed to Improve Spectrum Management*, Government Accountability Office, GAO-02-906 (September 2002) (available at: http://www.gao.gov/assets/240/235811.pdf).

Center at George Mason 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 10 years old and President George W. Bush issued a *Presidential Memorandum* in May of 2003 calling for a "Spectrum Policy Initiative" that would lead 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."[16] (This initial memo has served as a template for future such memoranda). 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, a proceeding that culminated in its *1991 Spectrum Report*.[17] The NTIA's report was comprehensive and innovative,[18]

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12 B. Skorup, *Reclaiming Federal Spectrum: Proposals and Recommendations*, MERCATUS CENTER WORKING PAPER NO. 13-10 (May 2013) (available at: http://mercatus.org/sites/default/files/Skorup_FederalSpectrum_v1[1].pdf) (hereinafter "*Mercatus Report*").

13 H. Feld and G. Rose, *Breaking the Logjam: Some Modest Proposals for Enhancing Transparency, Efficiency d Innovation in Public Spectrum Management*, Public Knowledge (June 2010) (available at: http://www.publicknowledge.org/pdf/pk-fed-spectrum-transparency-whitepaper.pdf) (hereinafter "*PK Report*").

14 T. Lenard, L. White, and J. Riso, *Increasing Spectrum for Broadband: What Are the Options?*, Technology Policy Institute (Revised: February 2010) (available at: http://www.techpolicyinstitute.org/files/increasing_spectrum_for_broadband1.pdf) (hereinafter "*TPI Report*").

15 *Supra* n. 7.

16 Available at: http://www.ntia.doc.gov/federal-register-notice/2004/presidential-memorandum-spectrum-policy-21st-century).

17 *U.S. Spectrum Management Policy: An Agenda for the Future, Spectrum Engineering Spectrum Management*, National Telecommunications & Information Administration, SP 91-23 (February 01, 1991) (hereinafter "*1991 Spectrum Report*") (available at: http://www.ntia.doc.gov/report/1998/us-spectrum-management-policy-agenda-future). 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 (1989). A number of government studies predated this piece. *See, e.g.*, F. Hopkins & W. Schummer, *Development of a Methodology for Improved Use of the Electromagnetic Spectrum by Federal Agencies*, ORI, Contract 50-SANT-4-03565 for NTIA (1985); OTP, *Management of Federal Spectrum Use*

(Footnote Continued. . . .)

calling 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 simply reiterate the findings and recommendations from the *1991 Spectrum Report*.

Dating from the NTIA's proceeding and report, the reform effort is now at least three-decades old, yet by the Government's own admission, almost no progress has been made. As the GAO concluded in 2011,

> … 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.[19]

Similarly, the *PCAST Report* concludes,

> There is [] a long history of failed attempts to implement significant reforms in Federal spectrum use.[20]

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.[21]

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through Shadow Prices: Can it be Rendered Practicable? (technical proposal submitted by General Electric Company - TEMPO Center 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* (Report prepared for OTP) (March 1973); and 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); J. H. Alleman, *The Shadow Price of Electromagnetic Spectrum: A Theoretical Analysis*, Office of Telecommunications, U.S. Department of Commerce (July 1974).

[18] This report is stunningly modern in its discussion of spectrum, as 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* n. 17 at Executive Summary.

[19] GAO-11-352, *supra* n. 11 at p. 9.

[20] *PCAST Report*, *supra* n. 5 at p. 55.

Efficiency has diverse meanings, so it is important to first consider exactly what the prior research means when it labels public use as "inefficient."[22] For this purpose, we turn to basic production theory. In the next two sections, we show that the most commonly proffered solution to the efficiency issue—that is, forcing the Government to face market prices—may help in some ways, but the implementation of such programs are not a panacea to the public agencies' inefficient use (or management) of spectrum over the long term.[23] There are a large number of details that must be addressed if such efforts are to be effective, including, especially, how such prices are set and how the levy of spectrum fees impacts the budgets of Government agencies. More critically, the government is not a profit maximizer, and 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 Section V, that the existing proposals do not go far enough. The 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 its spectrum assets efficiently. The *PCAST Report*, for example, states plainly, "Federal users currently have no incentives to improve the efficiency with which they use their own spectrum allocation …."[24] Likewise, the GAO concludes, Federal users "have little economic incentive to otherwise use spectrum efficiently."[25] The European Commission's *WIK-Consult Report* states, "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

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21 *Id.* at ix.

22 For a discussion of efficiency, s*ee also WIK-Consult Report*, *supra* n. 7 *passim* and in particular at p. 2.

23 A similar conclusion is reached in *WIK-Consult Report, id.*

24 *PCAST Report*, *supra* n. 5 at p. ix.

25 GAO-12-1018T, *supra* n. 11 at p. 12.

need it."[26] 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 to be useful. The label "inefficient" with regard to public spectrum use normally implies an excessive use of spectrum in the capital-spectrum input mix.[27] We use the standard economic model of production (i.e., the *isoquant*) 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.[28] In fact, we 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. A hypothetical public agency produces a collection of goods and services Q_0 using two broad classes of inputs including spectrum (labeled *S*) and other goods (e.g., capital equipment, labeled *K*). The isoquant labeled Q_0 illustrates 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-and-less spectrum the producer has, the greater-and-greater the amount of

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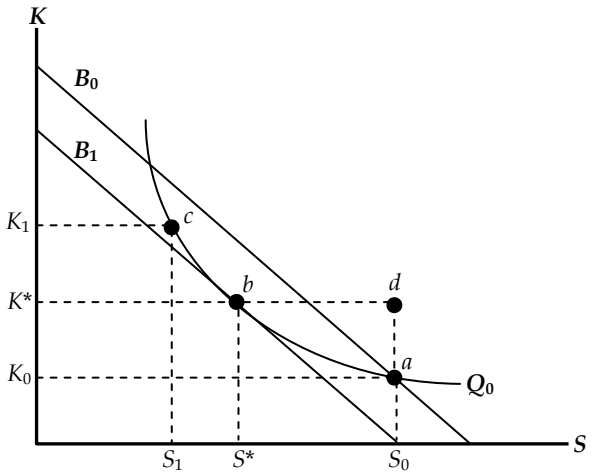
[26] *WIK-Consult Report*, *supra* n. 7 at p. 7.

[27] *See, e.g.*, OMB CIRCULAR A-11 (2013) at Section 31-12 (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.")

[28] The FCC uses this approach in its report, *Mobile Broadband: The Benefits of Additional Spectrum* (Oct. 2010) (hereinafter *FCC Technical Paper*) (available at http://download.broadband.gov/plan/fcc-staff-technicalpaper-mobile-broadband-benefits-of-additional-spectrum.pdf). The FCC paper mistakenly labels the isoquant as an "indifference curve." The indifference curve describes tradeoffs in consumption rather than production, though the improper use of terminology does not meaningfully impact the conclusions drawn from the analysis.

other goods required to maintain a fixed level of output.[29] 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



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* (i.e., uses 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 they are in the technical sense. However, their efficiency is directed solely towards their selection of K: the amount of S they use has been historically selected for them. (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

[29] For example, compare the additional amount of additional spectrum required in a 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).

technically inefficient, i.e., literally wasteful.[30]) The combination (S_0, K^*) is more costly than (S_0, K_0), yet produces the same output. This result illustrates one meaning of the "inefficiency" in public use of spectrum—i.e., *technical inefficiency*. Also, although one is tempted to say that the agency "pretends that the spectrum is free,"[31] this is not really so: the agency consumes the amount of spectrum they are allocated, not more than this. (In contrast, if spectrum was "free" as in the price was zero, then the agency may wish to consume more than their allotment.) Rather, if the agency is technically efficient, and carries out their mandate, then they will proceed to purchase the minimum amount of K necessary to their task (which is K_0 in the figure). Whether or not technical efficiency is a reasonable expectation of Federal agencies is a question beyond the scope of this PAPER.

It is not necessarily technical efficiency that presents the problem with the public sector's use of spectrum. Based on prior research, the relevant form of inefficiency with the production of Q_0 arises because the input S_0 has an opportunity cost: this spectrum could be used in the production of other goods or services. Thus, the issue is one of *allocative* efficiency, which relates to the allocation of goods and services in order 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 the simplest terms, suppose the input S has a fair market value of P per unit. If we take the price of a unit of the input K to be \$1 (for simplicity), then the agency is producing the output Q_0 at a social cost of $P \cdot S_0 + K_0$. Denote this amount of money as B_0, 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 on the figure. Notice two things about this line. First, B_0 passes through the point (S_0, K_0) since S_0, K_0 costs B_0. Second, though, B_0 is shown as being steeper than Q_0 at the point (S_0, K_0). This is an intentional choice, and its meaning will become apparent below.

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30 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^*.

31 *WIK-Consult Report*, *supra* n. 7 at p. 51 ("This is in contrast to the administrative approach in which spectrum requirements are expressed assuming the spectrum is in effect costless or "free".)

B. *Pricing Spectrum to Improve Efficiency – Or Not*

We consider now the possibility of implementing a price mechanism for S to attempt to cause the agency to adopt more efficient operations. Since the conversation about Federal spectrum reform is largely about shifting public spectrum allocations to the commercial sector to alleviate spectrum shortages, either as exclusive licenses or via a sharing paradigm, the basic problem is assumed to be one of public agency overuse (not underuse) of spectrum. One could imagine, for example, a system in which Government agencies might be 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 which motivates us here. Rather, we imagine that, in a social sense, the agency is *overprovided* with spectrum, and our goal is to reduce public use. This case 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 are needed to produce Q_0. Thus, the agency's operations are economically inefficient, this inefficiency arising from the overuse of spectrum and the underuse of other goods.

The extent of the social inefficiency implied by the input choice (S_0, K_0) can be easily illustrated. Suppose one reduced the hypothetical budget amount B_0 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" since the input choice (S^*, K^*) is the smallest budget which 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 then 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 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.[32]

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").

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.[33]

These statements reveal the nature of the inefficiency of Government spectrum use (allocative inefficiency), which can be traced partially to the "lack of pricing signals."[34] Given this defect, it is unsurprising that studies on the topic, both here and abroad, encourage the migration to an approach that requires public agencies to pay "market" prices for spectrum. For example, the *PCAST Report* concludes,

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[32] *WIK-Consult Report*, *supra* n. 7 at 50-1.

[33] *PCAST Report*, *supra* n. 5 at p. 55.

[34] *Id.*

> [r]equiring 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 quickly to a market mechanism so that Federal uses reflect their true social resource cost.[35]

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 users [could] encourage greater spectrum efficiency among [Federal Government] users."[36] In Europe, the *WIK-Consult Report* lays it 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".[37]

Furthermore, 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.[38]

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";[39] the *WIK-Consult Report* concludes, "there is a good case for

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35 *Id.*

36 *1991 Spectrum Report*, *supra* n. 17 at Executive Summary.

37 *WIK-Consult Report*, *supra* n. 7 at p. 50-52 (footnote omitted).

38 *Id.*

39 *1991 Spectrum Report*, *supra* n. 17 at Executive Summary.

the public sector to pay a price for spectrum that reflects its opportunity cost;"[40] 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."[41] While there is debate about 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 purported goal, it would seem sensible that 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 "ghost" market mechanisms proposed to address the failures of Government spectrum policy to promote efficiency in use, 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 people have set forth various proposals to improve efficiency in the public sector's use of spectrum. 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"). All of these proposals follow directly from the economic model of production discussed in the previous section. 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 Government's efficient 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 begin to 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

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[40] *WIK-Consult Report*, *supra* n. 7 at pp. 50-52.

[41] *PCAST Report*, *supra* n. 5 at p. 55.

spectrum. A commonly proposed approach to imposing market solutions 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 supposedly 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 paid to the U.S. Treasury. Use fees would be similar to rent paid to the GSA for office space in government-owned buildings.[42]

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.[43]

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,"[44] and the *WIK-Consult Report* suggests, "[t]here are different ways in which this payment could be implemented; the public sector could bid for

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[42] *PCAST Report*, *supra* n. 5 at p. 55; *see also Spectrum Management for the 21st Century: The President's Spectrum Policy Initiative Progress Report for Fiscal Year 2007*, U.S. Department of Commerce (November 2007) (available at: http://www.ntia.doc.gov/legacy/osmhome/spectrumreform/FY2007%20Progress%20Report_for_Fiscal_Year_2007_Final_25Nov08_rev_1Dec08.pdf); *Spectrum Management For The 21st Century: Plan To Identify And Implement Incentives That Promote More Efficient And Effective Use Of Spectrum*, U.S. Department of Commerce (2008) (available at: http://www.ntia.doc.gov/report/2008/plan-identify-and-implement-incentives-promote-more-efficient-and-effective-use-spectrum).

[43] *TPI Report*, *supra* n. 14 at p. 26.

[44] *Mercatus Report*, *supra* n. 12 at Abstract.

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*)."[45]

Despite its wide appeal, there are unfortunately a number of problems with this "spectrum fee" approach, some more significant than others. Here, we discuss three concerns, but there are certainly many others. First, at its best, such an approach is only a "ghost market" solution, since prices are not established in a market setting; another Government agency establishes the prices.[46] Obviously, price setting in this environment may be manipulated by political forces.[47] Prior to fully 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 on information spectrum transactions is limited. The lack 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, the commercial wireless carriers are very capable at valuing spectrum and do so regularly.[48] 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 any price for that matter) for spectrum, then the expenses of the agencies will rise by that amount (at least, initially). Most likely, the agencies will seek from Congress a budget adjustment for such expenses. The way a Federal agency's budget is

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[45] *WIK-Consult Report*, *supra* n. 7 at p. 52.

[46] *Id.* at fn. 11 ("… we generally refer to these mechanisms as *market-inspired* rather than *market-based*. 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).").

[47] *See, e.g., id.* ("… 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 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 (p. 45); it 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 opportunity cost of spectrum (p. 49).").

[48] There are hundreds of transactions involving the lease of spectrum between commercial providers, as detailed in the FCC's Universal Licensing System (available at: http://wireless.fcc.gov/licensing/index.htm?job=spectrum_leasing#d36e70).

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. Going further, suppose the charge implemented for S was in fact the market price P. However, since the agency has a responsibility to produce Q_0, we will assume they will be provided with some means (or budget) for doing so. There are several ways that the needed financial supplement could be calculated. We will 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 their choice of S (i.e., we assume technical efficiency, which, again, is a strong assumption).

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, $P \cdot S$. (Our research suggests this is the present GSA-style model.) In this case, of course, it is feasible for the agency to do nothing whatsoever: if they selected S_0 (its current allotment), then they would receive a supplement of $P \cdot S_0$, exactly offsetting their liability for "purchasing" S. Plainly, to continue to produce Q_0, complete inaction is feasible. A move to the efficient mix of inputs is expected from private firms because of profit maximization. But, Federal agencies do not maximize profits (or minimize costs).[49] There is no inherent incentive for the agency to alter its spectrum use or to use spectrum more efficiently.

What if, though, the agency selected a different level of S under this scenario? Any such choice in the direction of S^* would be more efficient from the social point of view but would 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, be sufficient to induce them to behave efficiently (in an allocative sense). The difficulty is the venerable observation that Government agencies rarely move aggressively to cut their own budgets. In fact, the budget consequences of such a plan led the authors of the *PCAST Report* to reject altogether the use of spectrum fees, where

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[49] *See, e.g., TPI Report*, *supra* n. 14 at p. 23 ("government agencies do not operate in a market context, and profit maximization is not their goal").

the report concludes "practical difficulties [] would render it ineffective."[50] The only "practical difficulty" 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. The *PCAST Report* states,

> … 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.[51]

In effect, the "practical difficulty" of the "usage fee" approach stems from budgetary actions by the U.S. Congress which work against the more efficient use of spectrum. Similarly, the *WIK-Consult Report* observes,

> 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.[52]

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50 *PCAST Report*, *supra* n. 5 at p. 55.

51 *Id.*

52 *WIK-Consult Report*, *supra* n. 7 at p. 52.

The simple economics of production suggests that imposing "market prices" on Federal agencies need not be sufficient to induce efficient behavior. Indeed, complete inaction is a viable choice, and one that may impose no costs on the agency. Absent a change in incentives, market pricing is not sufficient for meaningful reform. 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. Thus, the problem with the spectrum fee approach is more one of incentives than of technical feasibility. As we and others 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.

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 the spectrum the agency actually buys, but rather the amount it *should* buy. Prior proposals and research on this topic often suggest such efforts.[53] 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

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[53] The *WIK-Consult Report*, *supra* n. 7 at p. 49, suggests along these lines:

> 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.

The *PK Report*, *supra* n. 13 at p. 3, encourages more active management of federal spectrum requirements:

> 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.

agency could fulfill its charge to produce Q_0 is by selecting the efficient inputs (S^*, K^*). This approach is (theoretically) attractive, but what it means in practice is that the agencies themselves, or more plausibly some oversight agency, would be charged with determining the cost-minimizing plans, an extremely difficult task, and that some agencies might be confronted with very significant adjustments in their budgets. As noted by the GAO,

> 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 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.[54]

[54] GAO-02-906, *supra* n. 11 at p. 4.

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*

There is more evidence on the ineffectiveness of Government action to improve efficiency of spectrum use. President Bush's *Memorandum* from 2004, echoed in Circular A-11 in 2013, directs agencies to treat spectrum as an economic asset, an order presumably necessary because the agencies have no inherent incentive to do so:

> … agencies 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).[55]

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 spectrum valuation.[56] Still, such efforts are not independent of the agency using the spectrum, and nor are they independent of the Government. Absent independent verification, these valuations remain 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.

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[55] EXECUTIVE OFFICE OF THE PRESIDENT, *Improving Spectrum Management for the 21st Century* (November 30, 2004) (available at: http://www.ntia.doc.gov/files/ntia/publications/nov2004presidentialmemo.pdf).

[56] CIRCULAR NO. A–11, *Preparation, Submission, and Execution of the Budget,* Executive Office of the President, Office of Management and Budget (July 2013) (available at: http://www.whitehouse.gov/sites/default/files/omb/assets/a11_current_year/a11_2013.pdf).

2. *A Failure in Accountability*

It is presumably the case that a 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.[57]

Despite the obvious need for an accurate inventory of Government spectrum and its use, in 2012—over twenty years later—the Government has failed 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.[58]

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, there may be cases where a "gifted political executive" at a Federal agency is able to influence the efficiency of its programs and spectrum use.[59] However, such exceptions are no substitute for the systematic introduction of proper incentives.

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57 *1991 Spectrum Report*, *supra* n. 17 at Summary of Recommendations.

58 GAO-11-352, *supra* n. 11 at p. 16-7.

59 *See, e.g.,* J. Q. Wilson, BUREAUCRACY (1989), *passim* and at p. 217.

C. *Spectrum Currency as a Ghost-Market Mechanism*

In the place 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.[60] The purposes of spectrum currency are outlined 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.[61] Second, spectrum currency can be viewed as an asset rather than a cash flow, thus permitting longer-term planning and hopefully befuddling the counterproductive Congressional budget-setting process. Third, spectrum currency is an "incentive system" that attempts to motivate agencies to migrate to network architectures that permit sharing. This incentive system operates by permitting agencies to trade the *newly-created* artificial currency for "real dollars" from the *newly-created* Spectrum Efficiency Fund.[62] This proposal aims to create incentives to reduce spectrum needs by eventually trading-off 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 appears based on the simple logic illustrated in Figure 1. Federal agencies need some incentives, which they admittedly 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 the approach, a critical question is whether such 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')."[63] The answer is almost surely "No."

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60 *PCAST Report*, *supra* n. 5 at p. 55.

61 The *PCAST Report* proposes a new metric of spectrum use. *PCAST Report*, *id.* at p. 56, Section 2.2.

62 The Spectrum Efficiency Fund is "the broadened and repurposed Spectrum Relocation Fund … 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." *PCAST Report*, *id.* at p. xv.

63 *Id.* at p. 55.

Upon examination, the basic logic of spectrum currency is defective. Spectrum currency would be issued to agencies based on their existing spectrum holdings.[64] Spectrum currency can 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, if only indirectly. While *PCAST* believes that this "artificial currency" will not be appropriated by Congress in the same way as an outright cash sale, 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 is "*within* the Federal Government."[65] 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 both public and private entities.[66] At the center of the spectrum problem is spectrum shortages in the private sector, and 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, and the Government sector will continue to act as if it is cheaper than it really is. (That is, the budget line will not have the same slope as B_0 and B_1 in Figure 1.) Any potential gains will arise solely from reallocation of spectrum among Government users and not a reallocation of spectrum between the private and public users. Consequently, this pseudo-market scheme at best will work to eliminate some inter-agency inefficiency with the Federal Government, a laudable goal, but this approach does not address the problem of inadequate private spectrum—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, the Federal agency will not base its decision on the "true social cost" of that spectrum. Spectrum currency is not a solution to the efficiency problem.

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64 *Id.* at p. xv.

65 *Id.* at p. 55 (emphasis supplied).

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

D. *Other Options*

Finally, one can imagine somewhat more sophisticated schemes for simultaneously charging agencies for spectrum and appropriating funds to cover such outlays.[67] Some such 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.[68] Alternately, one could encourage reduced spectrum use by sharing the social gains with staff charged with increasing efficiency.[69] Other proposals include requiring public agencies to acquire spectrum at auction.[70] 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 have information sufficient to do a credible job. Introducing incentives for efficiency is always difficult in the public sphere, and 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.[71] But, inefficient use by Federal users is not the only problem; as noted by the *PCAST Report*, the "Federal system as a whole" does not have the incentives to improve efficiency.[72] The GAO points to the "limited progress toward improved spectrum management."[73] Thus, inefficiencies exist in both use

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67 For example, the *PCAST Report*, *id.* at pp. 55-6, proposes to use an artificial form of currency (*i.e.*, spectrum currency).

68 This approach would operate much like price cap regulation, where price declines over time based on an efficiency factor and thereby encourages increases in the efficiency of production. Given the nature of spectrum, however, implementing such an approach for spectrum is likely to be difficult.

69 *See, e.g.*, R. Klitgaard and P. C. Light, *High-Performance Government: Structure, Leadership, Incentives*, RAND Corporation (2005) (available at: http://m.rand.org/content/dam/rand/pubs/monographs/2005/RAND_MG256.pdf).

70 *WIK-Consult Report*, *supra* n. 7 at pp. 18.

71 *See* discussions in Sections II and III *supra*.

72 *PCAST Report*, *supra* n. 5 at p. ix; *see also WIK-Consult Report*, *supra* n. 7.

73 GAO-11-352, *supra* n. 11 at p. 9.

and management.[74] Inefficiency is systemic in government. As observed by the nation's leading authority on public administration, Professor James Q. Wilson:

> Government bureaus are less likely than private agencies to operate efficiently, at lease 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 given 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.[75]

Inefficient management is a significant concern, yet its implications have yet to be fully considered in regards to spectrum policy reform. As we see it, *it is the inefficiency of spectrum management, not spectrum use, which is most problematic.* If a Government agency uses office furniture or copy paper inefficiently, then the consequences of that inefficiency are almost exclusively limited to that agency.[76] The producers of office furniture and copy paper sell to many customers, face

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[74] The *WIK-Consult Report*, *supra* n. 7, for example, points to problems with the government being both judge and jury in regards to its spectrum use ("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 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*.") *Id.* at p. 45.

[75] Wilson, *supra* n. 59 at pp. 349-350.

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

significant competition and, as a result, are efficient in their operations. The fact that the Pentagon pays $750 for a hammer does not mean a consumer can't 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 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. 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 which require spectrum, such as national defense, and with public finance.[77] The discipline imposed by the GE set-up forces the analyst to account for *all* the effects of any proposed policy change within the context of the model. Even in the cases of those effects which 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, but to otherwise give the Government the benefit of doubt by assuming its motivations are pure and its operations are efficient within its own

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[77] In this way our model is consistent with the approach outlined in the *WIK-Consult Report, supra* n. 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.")

sphere. As will be apparent, relaxing these assumptions only strengthens our recommendations.

First, regardless of their 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 will 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 themselves. In other words, *it is not necessary to say that Government is inherently inefficient, only that there is an inherent inefficiency in having 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 auction of spectrum and Government leasing of spectrum to private users. Many of the proposals for spectrum reform include these options.[78] Both outlets will presumably provide revenue to the Government, either in the form of spectrum auctions or spectrum usage fees.[79] For reasons of realism, we will 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 will 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 obtained through government production. Certainly, the Government

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78 *PCAST Report*, *supra* n. 5 at p. 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.").

79 *Id.*

provides valuable services using its spectrum allocations. So, positive amounts of both public and private goods will characterize our equilibrium outcomes.

Fourth, we will emphasize and maintain the distinction, which has often been lost in debates over public spectrum, between spectrum which is leased by the Government, over which public control or management is maintained, and spectrum which is used in sharing arrangements. The issue of how spectrum can or should be shared among competing users is logically distinct from the question of whether such uses require public management of the spectrum resource. This latter claim—that sharing will happen only under public management—amounts to the assumption that government has some talent or ability unavailable to anyone else. This is a complicated 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. Thus, in the analysis that follows, one should keep in mind that leased spectrum refers only to previously government-owned spectrum which is made available to private users for private purposes in exchange for a fee, which is essentially the *PCAST Report*'s approach to spectrum 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.[80] 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 might be utilized by only one user. We will return to the issue of spectrum sharing below.

Finally, we will 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

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[80] *PCAST Report*, *supra* n. 5 at p. 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.").

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* unless one can offer a compelling virtue of Government intrusion in each specific case.

To formalize the argument, suppose the Government (any public authority) initially has a block of spectrum denoted S. This spectrum will be utilized in three ways. First, some quantity s_0 can be sold at a competitive market price r_0 to private users, who will then utilize 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. 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,

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;

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, 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 (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 under constant returns technologies. 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 $0 < \lambda < 1$.[81] Thus, the factor lambda (λ) captures this inefficiency inherent in government spectrum management (in the production of private goods).

Firms produce private goods, and they buy and lease spectrum for this purpose, as well as hiring employees. They maximize their profits to determine their demands for factors:

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

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, we obtain the competitive prices:

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

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

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[81] 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 + 0.5·80].

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. We will conventionally assume that labor supply must satisfy $0 \le L \le 1$, 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 Government through spectrum auctions or leasing is costlessly transferred to the private sector as a benefit. Thus, the household consumes consumption goods equal to its direct income $w^* + t$, and consumes that amount of the public good provided by 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 select optimal 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:

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

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

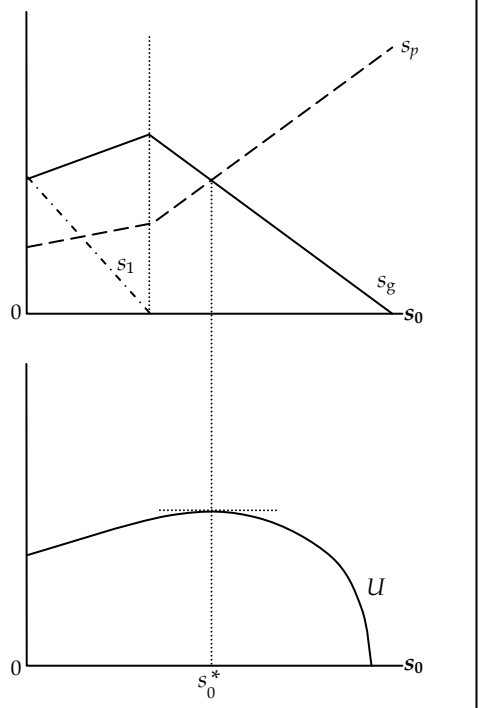
$$\partial t^* / \partial s_0 > 0 ; \quad (11)$$

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

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 illustrate this for some simple parameter values ($\theta = \alpha = \lambda = 0.5$, $S = 100$, and $A = 10$). In the top panel of Figure 2, private spectrum s_0 is measured on the horizontal axes and the variables s_p, s_g, and w 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



Several strong conclusions are summarized by the figure. First, the Government, given its *relative* inefficiency, should not be leasing spectrum to the private sector (a positive value of s_1 is not optimal). The result has a useful practical implication for policy making: any spectrum plan involving the Government leasing of spectrum to the private sector (e.g., the *PCAST* proposal) 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. (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.[82] 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 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 type licenses.[83]) However, in a market setting, such managed spectrum (s_1) will likewise sell at a lower cost. Thus, on the face of it, one cannot immediately see if 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 shows. The lower price 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 social welfare, wages and so on.

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-sectors' spectrum under a leasing

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82 For details on such sharing, see the FCC's Universal Licensing System (available at: http://wireless.fcc.gov/licensing/index.htm?job=spectrum_leasing#d36e70).

83 G.S. Ford, T.M. Koutsky and L.J. Spiwak, *Using Auction Results to Forecast the Impact of Wireless Carterfone Regulation on Wireless Networks*, PHOENIX CENTER POLICY BULLETIN NO. 20 (Second Edition) (May 2008) (available at: http://www.phoenix-center.org/PolicyBulletin/PCPB20Final2ndEdition.pdf); OFFICE OF INSPECTOR GENERAL, *Official Report: D Block Investigation* (April 25, 2008) (hereinafter "IG Report") (available at: http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-281791A1.pdf).

arrangement. We assumed also that the Government managed its own spectrum and did not lease it from the private sector (or some 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,

> … federal 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.[84]

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 (if any) incentives for efficient use, but the private sector has a powerful motive for efficiency (i.e., profit maximization).

Our model can be modified to consider this policy option. In the lower panel of Figure 2, we assume that s_1 must be non-negative (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 would be the private sector, then household utility (U) rises as s_0 increases across the entire range of s_0 (that is, 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 implementing a

[84] This is different than proposals to have all private sector spectrum returned to the government for shared use. *See, e.g.,* J. Kagan, *The FCC's Wireless Spectrum Band-Aid*, E-COMMERCE TIMES (October 4, 2012) (available at: 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.

> 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.[85]

As our theoretical model shows, and as the NTIA has previously concluded, the discussion of efficient use must not be limited to use, but also to spectrum management. If, as the *PCAST Report* concludes, the "Federal system as a whole" does not have the incentives to improve efficiency,[86] 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. The model form applied here is in many respects 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 the 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* is to patently reject any further spectrum clearing and auctioning in favor of "sharing" spectrum currently licensed to Government users.[87] Other proposals, though typically to a lesser extent than the *PCAST Report*, call for an expanded role for the Government in spectrum management. 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, there must exist cases in which Government management of some spectrum is, in fact, more efficient than

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85 *1991 Spectrum Report*, *supra* n. 17 at Section II.A.1.a.

86 *See, e.g., PCAST Report*, *supra* n. 5 at p. ix.

87 *Id.* at n. 10.

private management. Further, these "special cases" seem to coincide with opportunities for spectrum sharing which 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 *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 their 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, since this scheme merely trades off high prices from monopoly for high prices from inefficient production. Alternately, under spectrum exhaust (where output could not be increased economically by increasing the amount of capital applied to a fixed amount of spectrum), then rationing spectrum via government management would lower prices only if monopoly power was *absent*. Competition does not increase output or lower prices if output levels are strictly constrained by a scarce input.[88] If a monopoly is producing at the production constraint given available inputs, there is no difference between monopoly and any other market form.

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[88] T.R. Beard and D.L. Kaserman, *Testing for Collusion During Periods of Input Supply Disruptions: The Case of Allocations*, 46 ANTITRUST BULLETIN 213-226 (2000); T.R. Beard, G.S. Ford, L.J. Spiwak, M. Stern, *Wireless Competition Under Spectrum Exhaust*, 65 FEDERAL COMMUNICATIONS LAW JOURNAL 79 (2012); L. Froeb, S. Tschantz, and P. Crooke, *Bertrand Competition with Capacity Constraints: Mergers Among Parking Lots*, 113 JOURNAL OF ECONOMETRICS 49-67 (2003); A. Kalnins, L. M. Froeb, and S. Tschantz, *Mergers Increase Output When Firms Compete by Managing Revenue*, VANDERBILT LAW AND ECONOMICS RESEARCH PAPER NO. 10-27 (available at: http://ssrn.com/abstract=1670278 or http://dx.doi.org/10.2139/ssrn.1670278).

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 either the ability and/or the incentives to implement spectrum management practices which would make socially-beneficial sharing possible. 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.[89] If anything, the evidence suggests it is the private sector, not the public sector, that can oversee the widespread sharing of spectrum.

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. In such cases, the spectrum may be available for private sector users at certain times or locations, and sharing by the Government may be a sensible strategy in such cases 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, since 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 spectrum policy issue today 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 reveal that while the proposals to

[89] *See, e.g.*, 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. P. Goldstein, *Pentagon Strikes Deal with Broadcasters, Clearing Way for 1755-1780 MHz Auction,* FIERCE WIRELESS (November 26, 2013) (available at: http://www.fiercewireless.com/story/pentagon-strikes-deal-broadcasters-clearing-way-1755-1780-mhz-auction/2013-11-26).

improve efficiency may offer some benefits, the "market" approaches may not, in the long-term, do much to enhance efficiency.

Next, we turn to the question of efficiency in the Government's management of spectrum, which we take 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 level—the Government should control only the spectrum it requires to perform its duties. If the Government is a bad manager of spectrum, then it should not manage spectrum. Going further, any proposals that contemplate leasing of Government–managed spectrum to private parties for private use *may be presumed* to include too little spectrum auctioned for exclusive license. 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 which causes it to be so utterly unlike any other good so as to necessitate unique, speculative, and grossly bureaucratic methods of allocation and management. Everyone wishes Government was efficient. Realists, though, do not look to Government programs to make this happen. The reform of Government spectrum should involve a substantial shift to the private-sector's management of the nation's scarce spectrum resources.