A Comparative Analysis of Spectrum Management Regimes

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Abstract

Spectrum management influences the evolution of the mobile communications industry. Administrative spectrum management, market-based approaches, and commons approaches are analyzed. These methods have unique advantages and disadvantages and no single approach is superior on all counts. Optimal spectrum policy will have to determine the right mix of these methods rather than adopting one model.

1. Introduction

The growing demand for mobile services has led to a worldwide reconsideration of established methods of spectrum management. The potential flaws of the dominant administrative licensing process are known and include rigidity, long delays, and patterns of over- and under-allocation of spectrum to uses. Following the general trend towards a more market-based organization of the information and communications industries, an increasing number of countries have thus replaced administrative licensing procedures with spectrum auctions. However, there is a risk that the discussion proceeds without systematic exploration of options for spectrum management. Alternatives range from full privatization to the creation of common management structures. In the absence of transaction costs, the specification of ownership and disposition rights would not matter and an efficient solution would emerge regardless. However, under real world conditions of imperfect information, positive transaction costs, and strategic behavior the assignment of rights matters and will likely influence the evolution of the mobile industry.

Sound spectrum policy will have to understand this nexus and the advantages and disadvantages of alternative regimes. This paper attempts a preliminary exploration of these issues. The next section briefly reviews the tasks of spectrum management and approaches to pursue them.

Section three discusses the unique property rights constituted by different spectrum management regimes and offers a framework for their effect on industry evolution. Section four reviews four models of spectrum management and section five provides a comparative analysis of their key implications for mobile communications. The last section offers a few key conclusions.

2. Tasks and Approaches to Spectrum Management

There is widespread agreement that spectrum management should establish a framework optimizing the use of spectrum. Spectrum has several unique features that complicate this task. Unlike other physical resources it is fully renewable. However, there exist interdependencies among users due to signal overlay. While traditional radio communications is based on the assumption that spectrum has a limited carrying capacity and is therefore scarce, modern information theory challenges this assumption. Lastly, frequency bands have differing propagation characteristics and thus are not equally useful for all purposes. Efficient spectrum management has to address three interrelated problems. First, the correct amount of spectrum needs to be allocated to certain uses or classes of uses. Second, is needs to assign usage rights to certain users or groups of users. Third, it needs to adjust established policies as technology and markets evolve over time.

Given these physical characteristics of spectrum, optimal spectrum policy should be designed to secure efficient use of spectrum. Optimal spectrum policy is always contingent on the state of technology. Efficient use implies that, given the state of technology, spectrum is channeled to its most productive uses. Spectrum policy should also create incentives to use given spectrum more efficiently (internal margin) and to expand the useable range of spectrum (external margin). As spectrum uses change over time, an efficient regime also needs to minimize the transaction costs associated with these adjustments. Last but not least, spectrum policy pursues other non-market objectives such as national security, safety and equal access goals.

Spectrum management regimes provide frameworks for addressing these tasks of spectrum management. Historically, based on the radio technology of the 1910s and 1920s, a regime of exclusive licensing was established, in which all tasks of spectrum management were done in

national and international administrative processes. With the tremendous growth in applications for licenses, the weaknesses of the administrative approach, including long delays, the impossibility for the government to pick the most promising proposals, and the lack of economic incentives to use spectrum efficiently, became overly clear. In response, many nations have experimented with more flexible forms of licensing (in this paper called "licensing+"). For example, bands were made available for a range of uses rather than just one and licensees were given the privilege to split or aggregate spectrum. Most importantly, auctions were introduced to assign spectrum to users. Auctions are embedded into an overall administrative framework, which creates some potential disadvantages. Some experts have responded with the proposal to create more comprehensive spectrum ownership. Others endorse the creation of common resource management regimes. These approaches differ in the way they assign property and disposition rights over spectrum (see table 1). The first three regimes establish exclusive rights, whereas the latter does not create exclusive privileges. A broad literature on the implications of differently specified property rights exists and can be explored to better understand the likely consequences of different spectrum management regimes.

Table 1

Elementary features of spectrum management regimes

	Exclusive rights			Non-exclusive rights
	Licensing	Licensing+	Ownership	Commons
Allocation	Government planning	Government planning	Endogenous (owners), government	Endogenous (users), government
Assignment	Administrative process	Auction	Auction, market transactions	Auction of usage rights or users
Dynamic adjustment	Government planning	Government planning, licensees	Market transactions	Users

Inefficiencies can be introduced at any one of the levels of spectrum management. Inappropriate attention to the allocation of spectrum will distort otherwise efficient assignment methods (Melody 2001). Even if an efficient allocation is established at a particular point in time, it will

have to be continually adjusted to reflect technological advances and changing market conditions. In general, new applications in hitherto unused frequency bands pose fewer problems than modifications in occupied spectrum bands, as existing users will have to be migrated to other frequency bands (or shifted off the air entirely) and possibly compensated for stranded investment.

3. A Property Rights Perspective

A vast literature has clarified that property rights are complex bundles of rights and obligations. Spectrum management regimes also define different bundles of property rights. Several principal spectrum management regimes are possible: 1) licensing and licensing+, 2) ownership; 3) common property; and 4) open access. These approaches differ in how they define rules for spectrum access and use; management of a certain band; exclusion of others from that band; and alienation, that is the right to sell or lease spectrum to others. In a private property regime the owners of spectrum can execute all these rights. In an open access setting, everybody would have access to the spectrum resource but no user enjoys any of the other rights. Although these models have recently attracted an increasing number of supporters they are currently the exception rather than the rule.

While spectrum differs in important respects from other forms of common property resources, such as fisheries or forests, important insights can be gained from the vast literature on common resources. Various specifications of property rights are possible within a common property framework (Ostrom 1990, Stevenson 1991). Researchers in the commons tradition have identified four different roles based on the assignment of rights: authorized users, claimants, proprietors, and owners. Authorized users only have the limited right of access to and use of the resource. Claimants have management in addition to usage rights. Proprietors also have the right to participate in decisions excluding others from the use of the resource. Owners have all these rights plus the right to sell or lease their use. The only difference to pure private property is that common resources usually restrict ownership rights in the interest of the common good. Thus, the governance options for spectrum management within a common property framework span a range that touches on private property on one end and on open access on the other. A key

question for spectrum management is how efficient these alternative are and how they influence industry performance. As table 2 illustrates, the four spectrum management regimes also differ in which participants in the mobile markets are involved in important decisions.

Table 2

Locus of decision-making under different regimes

	Licensing	Licensing+	Ownership	Commons
Spectrum use (band, power, time)	G	G	G initially, O thereafter	G. M, U
Standards, protocols	L, M, G	L, M, G	O, M, G	M. U
Content, format	G, L	G, L	O	U
Specific content	L, U	L, U	O, U	U

G … government, L … licensee, M … equipment manufacturers, O … owners, U … end-users. Inspired by Benkler (1998).

The historical approach of exclusive usage rights through administrative or market-based licensing shares features of a common property model (as no formal ownership rights are established) and of the ownership model (as licenses are typically renewable and rarely revoked). Licenses typically give temporary, exclusive usage privileges to an individual or an organization as long as certain eligibility criteria are met. Most licenses also can be transferred to third parties as long as these meet the same eligibility test. This transferability is not equivalent to the right of alienation granted by full ownership rights. However, licensees typically do not have direct rights to participate in the management of the spectrum resource nor do they have a direct voice in determining who should be excluded from spectrum use. In terms of the common property research, spectrum licensees resemble the role of the authorized user.

4. Licensing+ and Ownership

Administrative licensing has some potential advantages and, if flawlessly implemented, would allow the pursuit of non-price goals in an efficient manner. However, perhaps with the exception

of very small countries or countries with a tradition of highly efficient and qualified administration, it is unlikely that administrative licensing can be executed in such an ideal fashion. Some of the flaws of administrative licensing can be remedied by auctions, which allow the placing of a market value on spectrum, are transparent and not easily prone to manipulation. In the U.S. auctions have shortened the licensing process from 48 to 4 months on average. However, auctions are still embedded in the rigid framework of administrative processes. For example, if an inefficient amount of spectrum was allocated to a service the price determined in an auction will reflect a scarcity (or abundance) rent rather than the true value of spectrum. This holds independently of how the auction rules are specified. Moreover, recent research has challenged one of the basic premises of the auction model, namely that the subsequent evolution of the market is unaffected by the auction due to the sunk nature of the market entry cost. Offermann and Potters (2001) find in experimental research that auctions result in higher prices. Bauer finds weak evidence that prices for GSM and PCS service are higher in markets with higher license fees. While these results do not question auctions per se, they point out previously unnoted costs that will have to be included in an overall assessment of their comparative performance.

After early proposals to establish private property rights for spectrum in the 1950s (Herzel 1951, Coase 1959) were largely ignored, this model is currently receiving renewed attention in more or less radical versions. Privatization requires the initial assignment of private property rights, typically using a market-based mechanism such as spectrum auctions. For existing licensees, Spiller and Cardilli (1999) have suggested the auctioning of warrants to convert existing usage privileges into ownership rights. Kwerel and Williams (2001) have proposed to use a one-time auction to convert existing licenses into full property rights in spectrum. In principle, the private property model can solve the three problems of spectrum management simultaneously as market forces drive allocation, assignment, and dynamic adjustment.

So far, there is only limited experience with privatization of spectrum in New Zealand and Guatemala. However, serious conceptual objections were raised against spectrum markets, including the pervasiveness of externalities, the noncompetitive nature of wireless markets, and the fact that large portions of spectrum are used by non-profit organizations or for purposes that

defy market pricing (Melody 1980). In order to function well, spectrum markets would have to be very liquid and auxiliary markets, such as futures and derivative trading, would have to evolve. Assembling spectrum bands in contiguous geographic areas may be plagued to very high transaction costs, introducing a new type of inefficiency. There is also reason to believe that the owners of spectrum would not make unused spectrum available at the margin, especially if it could be used to provide competitive services. Ideally spectrum would be made available if it incurs positive opportunity costs. However, an owner facing potential competition will only make spectrum available if the difference between the opportunity cost and lost profits is positive. The welfare implications of this risk of spectrum hoarding need to be explored in more detail. Last but not least, where international frequency coordination is necessary and spectrum is allotted to regions, a private market mechanism may raise serious equity issues. Whereas some of these issues probably could be overcome by appropriate institutional design, privatization does not offer a panacea.

5. Commons and Open Access

Licensing+ and ownership establish exclusive rights for spectrum. Such exclusive rights are challenged on constitutional grounds as a violation of the freedom of speech. They are also challenged as a framework that is inferior to more open arrangements. During the past decade interest in common property resources and the conditions of their successful management has grown. In the course of this debate, several of the tacit premises of the earlier commons debate were reconsidered. Among other things it became clear that the famous "tragedy of the commons" is a misnomer as the phenomenon typically only occurs in unmanaged, open access property regimes. In contrast, empirical studies of common property arrangements have found that the specific assignment of property and disposition rights in common property resources has a strong impact on the efficiency of their use. Authorized user models are less efficient than proprietor or owner models, as the latter have higher incentives to invest into the development of the resource (Ostrom 1990).

It is therefore a legitimate question whether a modification of property rights within the common property framework would improve the efficiency of frequency management. One particularly

interesting suggestion is the reliance on more community-based arrangements for spectrum management. Two rationales can be associated with these proposals. It is first pointed out that recent advances in spread spectrum technology eliminate the necessity of assigning a specific channel to a user. Interference is not seen as a problem of signal transmission but rather of the receiver. Intelligent receivers can decode signals from complex overlay patterns. For example, ultra-low power code division multiplexing allows the orderly use of broad bands by competing uses and users. As the efficiency of spread spectrum technology increases, ever more applications may be able to use the same spectrum band. This would allow a radical reorganization of spectrum management. Exclusive usage privileges would not be required for an orderly use of spectrum they would even become unconstitutional (Benkler 1998). Spectrum could be shared and managed by the user community based on rules developed in a decentralized fashion (Buck, forthcoming).

Second, the proponents of this position point to the specific nature of innovation and the new organization of the production process in advanced information and communication industries. Innovation in information industries is often cumulative, with developers of information goods and services highly dependent on access to previously created knowledge. Likewise, there is anecdotal evidence and a swelling conceptual debate linking the speed of innovation on the Internet to the availability of an open access platform (Bar, Cohen, Cowhey, DeLong, Kleeman, and Zysman 2000, Lemley and Lessig 2001). The next generations of mobile communications will resemble the value chain in the fixed Internet and a large innovation impetus is expected from open access to the wireless network platform. The current use of auctions will likely increase the incentive of network providers to close access to their own affiliates, reducing the overall dynamics of that sector. Therefore, the development of spectrum as a commons is seen as crucial in supporting innovation processes and maximizing the benefits from advanced mobile communications.

As this discussion illustrates, spectrum commons are to be distinguished from open access models. Open access models are at best a commons regime with a very weak set of rules governing market access. Table 3 summarizes key features of different proposals. One model to combine open access with the utilization of market forces is advocated by Noam (1998). He

endorses opening access to spectrum but proposes the introduction of market-based fees to reflect the opportunity costs of spectrum. This model would allow the establishment of futures and derivative markets in spectrum and hence would allow users to sign long-term contracts. As it would convert sunk license fees determined in an auction into variable payments determined in spot and future spectrum markets, the proposal would avoid some of the potential distortions of auctions. A key problem in this approach is that so far no workable mechanism has been devised for the collection of the spectrum fees.

Table 3

Range of common property and open access regimes

	U-NII (FCC, 1997)	Open access Noam (1998)	Spectrum commons (Buck, forthcoming)
Access	Open, subject to minimal etiquette rules (power levels, listen first, …)	Open subject to purchase of access tokens	Rules developed by stakeholders
Congestion management	---	Continuous auctions of access tokens	Rules developed by stakeholders
Standards development	Industry within FCC-mandated framework	Government, industry, users	Rules developed by stakeholders

Another type of open access framework was established by the U.S. Federal Communications Commission, which has designated more than 300 MHz of spectrum in the 2 GHz and 5 GHz bands as unlicensed. Critics point out that the experiments with unlicensed spectrum have resulted in low investment and local overuse. These observations would indicate the weaknesses of the commons model of spectrum management. However, it seems that the major flaw of unlicensed spectrum is the lack of rules that would allow its systematic utilization. Buck (forthcoming) discusses eight meta-rules for a spectrum commons, including a clear definition of boundaries, congruence between appropriation conditions and local conditions, collective choice arrangements, and appropriate monitoring procedures. Based on general insights from the commons literature, these rules could create a structured environment for spectrum use without creating exclusive rights based on financial strength.

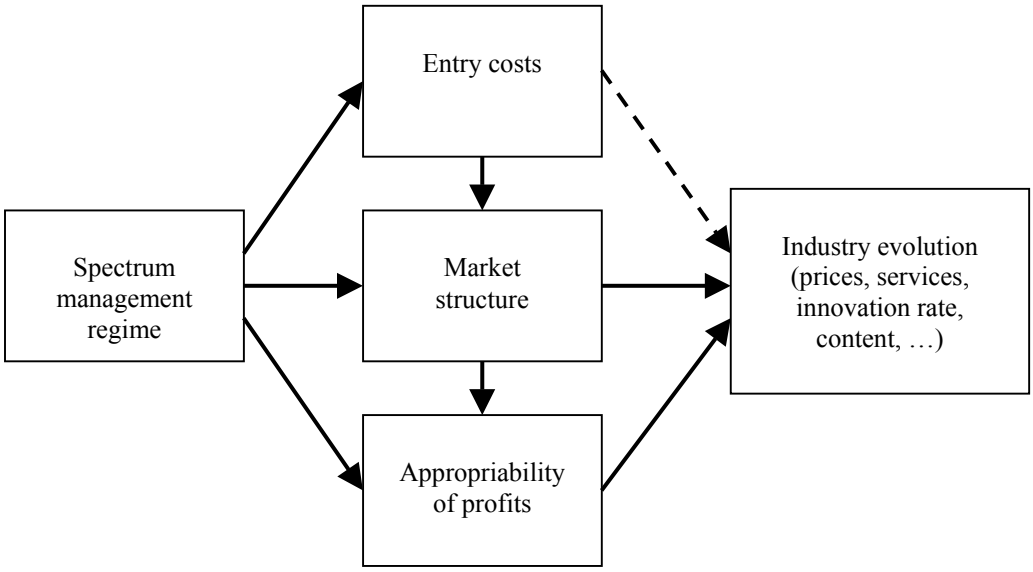
Spectrum commons are an alternative institutional arrangement for addressing the three issues of spectrum management. Like privatization, in principle they could address allocation, assignment and dynamic adjustment simultaneously without the disadvantages associated with financially driven spectrum markets. Moreover, they would allow modifying broad principles of spectrum management based on the needs of the local user community. However, this approach is afflicted with potentially significant transaction costs. These will in part depend on the state of technology and application in question. If an application requires national or even international allocation of a specific band, a commons-based approach may be too cumbersome and not be very different from the status quo of ITU spectrum management. On the other hand, if local mobility and interconnectivity are the main objectives, the model may be superior to the existing administrative process and more market-based alternatives.

6. Toward a Comparative Analysis

The different regimes constitute particular sets of ownership and disposition rights whose implications for the evolution of mobile communications can be subjected to systematic analysis. Figure 1 presents a simplified framework for such an endeavor. Spectrum management regimes affect industry evolution via three intermediate variables: entry costs, market structure, and the appropriability of profits. As the previous discussion illustrates, spectrum management regimes have direct consequences for the entry costs of mobile service providers. Under administrative licensing these are the indirect costs of handling the sometimes time consuming process. Under a regime of spectrum auctions, entry costs also include the competitively determined bid. The various commons regimes have different implications for entry costs and may range between an auction regime and free access. The U-NII model does not incorporate any form of congestion management and thus does not impose any specific license fees. Noam's model is based on congestion fees with the presumption that they would be zero most of the time. In addition to the level of entry costs, the nature of these costs differs significantly. For example, in the auction model they are sunk costs whereas in Noam's open access model they are spectrum lease fees. Whereas sunk costs may lead to increase market concentration and ensuing disadvantages, spectrum lease fee probably do not have such undesirable effects.

Figure 1

Spectrum management and industry evolution



Spectrum management regimes also directly affect the market structure of the mobile communications industry in addition to their indirect effects mediated through sunk entry costs. The relationship between market structure and industry performance and evolution is well understood and need not be discussed here in significant detail. Of particular importance is the effect of the market structure on the innovation patterns of the mobile industry. To fully understand this link, it is also necessary to capture the effect of the spectrum management regime on the appropriability of profits. Other things equal, exclusive licensing regimes facilitate the appropriation of innovation premiums by a licensee. Non-exclusive regimes do not allow a user to protect an innovation through exclusive control over spectrum space. However, they allow appropriation of innovation rents based in other features, such as intelligent terminals, service features, and the like. It is important to realize that spectrum management is not the only determinant of appropriability, which is also strongly influenced by the market structure of an industry.

Table 5 summarizes some of the insights derived from such an approach. It illustrates that there are systematic differences and trade-offs between the spectrum management regimes. With regard to static efficiency, spectrum management regimes to the right score better. Owners of

Table 4

Effect of spectrum management on determinants of industry evolution

	Licensing	Licensing+	Ownership	Commons
Entry costs	No direct, indirect	Bid price (sunk) plus indirect	Bid price (sunk) market price	Dependent on access rules
Market structure	Determined by government	Determined by government	Sunk costs, competitive strategy	Self-regulation
Appropriability	Dependent on market structure, potentially high	Dependent on market structure, potentially high	Dependent on market structure, potentially high	Dependent on access rules

Table 5

Spectrum management and industry performance

	Licensing	Licensing+	Ownership	Commons
Static efficiency	Dependent on market structure, often low	Dependent on market structure	Likely high	Very high if proper incentive structure
Dynamic efficiency	Dependent on market structure, often low	Dependent on market structure	Dependent on market structure, likely high for projects with high R&D	Likely most conducive to innovations with low R&D
Transaction costs	Under ideal conditions low	Under ideal conditions low	Unknown, could be high	Unknown, could be very high

spectrum have strong incentives to utilize spectrum efficiently. However, we also found situations in which the incentives of owners deviate from the social optimum and spectrum hoarding may result. Under a managed commons regime, rules are typically specified to create strong incentives to increase the efficiency of spectrum use, both at the internal and external margin. Administrative licensing typically provides only very weak incentives to achieve dynamic efficiency although this is to a large degree influenced by the market structure defined by the licensing regime and other policies. As ownership enables a firm to utilize spectrum to increase the appropriability of an innovation premium, it seems most conducive to innovation processes characterized by high innovation risk. On the other hand, commons models do not

allow enhancing appropriability of an innovation premium through spectrum control and therefore may be more appropriate in situations with lower innovation costs and risks.

Lastly, with respect to transaction costs more detailed research is necessary. Licensing and licensing+ in theory could be implemented with fairly low transaction costs although this is rarely achieved in practice. The transaction costs of ownership and commons regimes are not known but could be substantial. This preliminary analysis indicates likely trade-offs between the studied spectrum management regimes. It is likely that these differential properties are appropriate for different aspects of the wireless industries. Rather than searching for the "best" spectrum management regime, it may therefore be more important to find ways to determine which mix of regimes should be implemented.

7. Conclusions

Despite the strong push towards privatization, spectrum policy can pick from a broad range of options. As the brief discussion illustrated, these different approaches define systematically different sets of property rights. In turn, they will influence pricing, investment and innovation processes in the wireless industry. Given the vast range of uses of spectrum it is unlikely that one model will suit all situations. Both more market-based models as well as commons-based proposals have unique advantages and disadvantages. It will be necessary to carefully monitor the experience with these approaches. The coexistence of multiple institutional arrangements for spectrum management should facilitate a better understanding of their impacts for the evolution of wireless markets.

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