Allocative vs. Technical Spectrum Efficiency

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Abstract

Achieving allocative and technically efficient spectrum management is a key aspect of deregulatory reforms in several OECD countries. However, reform legislation offers few clues as to how these objectives should rank when they conflict with one another. An ‘innocent’ prior acquisition of service-neutral spectrum at an efficiently run auction may prove allocative efficient but fail to be technically efficient if the spectrum is left fallow in the short-term. Accountability for the productive usage of a public resource and pressures from short-term political cycles may induce regulators to mandate some minimal level of activity. Two plausible regulatory responses are considered: use it or lose it clauses and spectrum trading incentives. The former favours technical efficiency whilst the latter promotes allocative efficiency. The argument is formalised in a simple economic model buttressing the roles of uncertainty and transaction costs to assert the primacy of allocative efficiency over technical efficiency.

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1. Introduction

In the long run, the economic performance of sovereign nations rests on the efficient use of scarce strategic resources such as the radio spectrum. Achieving efficient spectrum management is of particular importance for the expansion of the information and communications industries, with flow-on benefits for the consumers and communities they
serve. However, traditional command and control regulations such as currently applying to many legacy services worldwide present an obstacle to objectives of efficient usage.

Accordingly, achieving efficiency in spectrum allocation, use and access became the central tenet of legislative reforms introduced at varying degrees in several spectrum liberalising countries about a decade and a half ago. As is well established in the spectrum regulation literature, there are various ways of thinking about efficiency in spectrum policy and concepts such as allocative-, productive-, technical-, dynamic- or functional efficiency are commonly put forward as building blocks in the overall quest for spectrum efficiency (Burns, 2002; Cave, 2002; FCC, 2002; Cave, Doyle, & Webb 2007).

How these efficiency sub-objectives are to combine in the promotion of the public interest remains a vague proposition. In particular, is the systematic and simultaneous pursuit of allocative (highest value) and technical (most intensive usage) spectrum efficiency feasible? If the answer is yes, achieving these objectives will unambiguously contribute to the maximization of an overall efficiency measure. Otherwise, if these distinct efficiency concepts mutually exclude each other, pursuing one of them will come at the expense of the other. This situation may lead to wasted opportunities and welfare loss if the socially weaker objective replaces the stronger one.

As this article illustrates, regulators commonly encounter such intricate trade-offs between different efficiency objectives. With little objective criteria to guide their decisions, they

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1 A comprehensive, comparative review of the licensing reforms in these countries can be found in Marcus, Nett, Scanlan, Stumpf, Cave, and Pogorel (2005), and more briefly in Annex A of Hazlett (2008).
2 A referee stresses the importance of semantics in efficiency definitions, suggesting that it might be technically efficient, when irreversibly investing in new technologies, to leave spectrum unused for a short period while a new, more ‘technically’ efficient technology is developed. This definition refers to an optimal resource usage problem, at times described as ‘dynamic efficiency’ (Cave et al., 2007). This concept is simply ‘allocative efficiency over time’: the outcome of a long-run process optimally migrating resources to where they are needed most in social welfare terms (regardless of short-term periods of resource non-use). Risk aversion and time preferences fully shape this process. By contrast, technical efficiency is a throughput measure, referring to the continuous, intensive usage of the resource, often to satisfy short-term regulatory targets (such as set by the demands of political cycles).
have generally tried to steer a course between the requirements of legislated texts, and the interests of spectrum users and their consumers.

This is problematic in many ways. Spectrum management reforms have created leasehold property rights regimes, such as auctioned and used in New Zealand (management rights), Australia (spectrum licenses) and the United Kingdom (spectrum usage rights). When competitively auctioned, spectrum property rights provide ideal pathways to achieving allocative efficiency but they are not necessarily technically efficient, in the sense that the spectrum may remain largely unused. Therefore, property rights and auctions may help channel the spectrum to where it is valued most, but they offer no guarantee of efficient use (or any use at all).

Conversely, administrative licensing arrangements that facilitate the productive use of a specific frequency band will usually not be allocative efficient because the deployed service or the adopted technology are typically prescribed with no regard for market forces.

Hence, efficiency objectives can diverge significantly from one another in practice and the type of licensing regime adopted can itself be a source of divergence through the transaction costs they impose and the incentives they generate. With competing efficiency objectives, the quest for efficient spectrum policy presents daunting public interest dilemmas to regulatory agencies, and as will be discussed, spectrum law offers little guidance to help clarify these choices.

This article aims to contribute to a clearer hierarchy of spectrum efficiency objectives. A first section stresses the lack of clear direction in legislated and regulatory texts in major spectrum liberalising countries (where the emphasis on spectrum efficiency objectives is
highest). A second section illustrates the regulatory problems arising from this lack of direction through a practical example of conflicting efficiency objectives in Australia. A third section discusses two approaches used by regulators to resolve the conflict between allocative and technical efficiency: facilitating spectrum trading and inclusion of `use it or lose it' clauses in the licensing contract. Finally, the paper presents an economic model, which sheds some light on the relative economic efficiency of these two approaches. The basic point is that, in general, `use it or lose it' restrictions fall short of achieving efficient allocation of spectrum because they distort the dynamic investment decisions of market participants. This result highlights the crucial role of a well functioning secondary market for spectrum in achieving both allocative and technical efficiency in spectrum use.

2. Efficiency objectives in selected reform countries

Consider several efficiency objectives as articulated by several key jurisdictions in spectrum-liberalising countries. In the US, the Spectrum Policy Task Force (SPTF) of the Federal Communications Commission (FCC) has repeatedly stated that:

`One of the Commission's key spectrum management goals has been to promote efficient access to and use of the radio spectrum' (FCC, 2002, p. 4)

Does efficient access implicitly lead to efficient use, or do these two objectives contribute separately and independently to an overall efficiency goal? To clarify its intentions, the FCC distinguished between (FCC, 2002, p. 5-9);

(i). Spectrum efficiency, which is a narrowly defined input-output ratio referring to the maximum information throughput that can be dispatched per unit of radio spectrum;
(ii). Technical efficiency, which combines spectrum efficiency with the cost of using other resources\(^3\): a highly spectrum efficient device may be technically inefficient if it is too costly in terms of other resource use, say specialised labour, new equipments or managerial time;

(iii). Economic efficiency, which is the ratio of output value over inputs cost and differs from throughput definitions by measuring value rather than quantity (output value varying from utility value for TV programs to the value of a life saved, say as measured by QALY methods).

Importantly, the SPTF stresses (correctly) that ‘spectrum and technical efficiency feed into and become a component of economic efficiency’ (FCC, 2002, p.6). High rates of spectrum and technical efficiency may just be too costly to achieve compared to the benefits they create to society as a whole. This type of analysis seems to support the pursuit of allocative efficiency. Accordingly, the FCC supported the following reforms: (1) more exclusive usage rights (e.g. allowing subdivision, trading and service neutrality) when transaction costs associated with market negotiations and contracting are low, and (2) spectrum commons open to all on a non-interfering basis when scarcity is low and transaction costs of market mechanisms are high (FCC, 2002, p.32-34).

Is this a widely shared view of efficiency in spectrum policy? In the United Kingdom, the Communications Act 2003 (the Act 2003) requires that spectrum policy should lead to:

‘the efficient use in the United Kingdom of the electro-magnetic spectrum for wireless telegraphy’ (§152, s.5, HMSO 2003)

\(^3\) Note that this definition of technical efficiency differs from the one used in this paper (which emphasizes continuous and intensive usage) and is closer to what Cave et al. (2007) refer to as ‘productive efficiency’.
As the Act 2003 does not discriminate amongst specific efficiency objectives, Cave et al. (2007, p.169) further suggest that 'efficiency in this context is usually understood to mean economic efficiency'. Economic efficiency relies here on the Pareto criteria, that is, being able (or not) to improve the well-being of one economic agent without harming that of another. Cave et al. (2007) further decompose economic efficiency into:

(i). Productive efficiency: least cost production of a given output;
(ii). Allocative efficiency: producing a bundle of services so composed that no other bundle could improve the well being of an agent without harming that of another agent;
(iii). Dynamic efficiency: using the resource in such a way that it enables long-term productivity improvements such as through innovation and R&D.

Which of these co-objectives should have higher priority? Cave et al. (2007) emphasise the potential complementarities of these objectives in an ideal world of perfect competition. For instance, they show how a reallocation of spectrum resources between sectors with different marginal benefits from spectrum use can increase both allocative and productive efficiency - by freeing other resources, which prices and quantities can then be used to value the reallocated spectrum. This discussion sets a benchmark to develop pricing mechanisms but the authors are well aware that in practice radiocommunications markets bear little resemblance to their ideal, frictionless environment.

In Australia, the Radiocommunications Act 1992 (the RCA 1992 Part 1.2, Section3, Attorney General's Department, reprint 3, 2005) stipulates that its first objective is to:

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4 The First Fundamental Theorem of Welfare Economics demonstrates that under conditions of perfect competition (free entry, zero transaction costs, free flow of information, etc.) objectives of productive (technical) and allocative efficiency are jointly maximised. This arises out of relative prices equilibrating the cost of providing one service in terms of forgone quantities of another service with consumers' relative value of these services.
`maximise, by ensuring the efficient allocation and use of the spectrum, the overall public benefit derived from using the radiofrequency spectrum'.

As elsewhere, the RCA 1992 does not stipulate which of `allocative' or `usage' efficiency should prime in the pursuit of the public interest; neither does it provide an interpretation of these objectives or suggest how to pursue them. In p. 86 of its 2002 Radio Communications Inquiry, Australia's Productivity Commission describes objectives of efficient usage and access as generally unclear, subservient, or unnecessary, emphasising clause (a) of the Act (efficient allocation) as the supreme objective to pursue (Productivity Commission 2002). This recommendation proved polemical. Regulatory authorities were quick to stress that the sole pursuit of allocative efficiency does not guarantee continuous and intensive usage. No amendments were made to the RCA 1992 and the three objectives remain equally enshrined in legislation.

Hence, the common thread in policy prescriptions amongst reform countries is a certain degree of indecision about the type of economic gains pursued by reforms, and an implicit assumption that regulatory agencies will exercise their discretionary powers to select appropriate efficiency objectives where relevant. For some frequency bands, this degree of indecision is leading regulatory agencies into impasses. In Australia, property rights approaches have generally proved allocative efficient, but as reported below, in almost...

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5 The term `allocation' also offers considerable potential for semantic confusion. In spectrum policy, the term usually refers to the designation of a band for a specific service or range of services. These designations are generally determined through ITU-R regulations but some countries, such as Australia, leave some discretion to owners of property rights spectrum to change the nature of the services provided, thus encouraging `allocative efficiency' (using and migrating resources where they are most valued at any point in time). Another common confusion lies with the role of auctions. Auctions `assign' rather than `allocate' spectrum to users. The fallacy that property right spectrum is allocative-efficient because it is auctioned is plainly wrong not only because many auctions are far from being competitively run, but also because auctions do not `allocate' they merely `assign' spectrum to a licensee or an owner. It is the property rights (not the auctions) that enable allocative efficiency by matching service provision with market demand. In our view, the 2.3 GHz licences are efficiently allocated because they were (1) assigned to the user who valued them most at auction, and (2) the underlying property rights allow this owner discretion to deploy the service/technology that best meets his/her market (in that case through a `wait and see' strategy) and (3) there is no evidence the `wait and see' strategy is driven by objectives of market power and foreclosure (which would invalidate allocative efficiency)
half of the cases the owners made scant use of the spectrum licences, building no infrastructure, deploying no network, nor even trading the spectrum with potentially interested secondary users. This is not necessarily a point of concern from an economic point of view, especially for new services and technologies. As Cave (2010 : 258) remarks: ‘...there may be good reasons - and not anti-competitive ones - to acquire spectrum ahead of use. Having guaranteed access to spectrum may be a precondition for making more substantial investments in technological development...’. Nevertheless, situations like these give momentum to demands by direct competitors and other market players with an interest in the spectrum to implement some form of contractual obligations. One such mandate consists of imposing ‘use it or lose it’ clauses, which would give licensees incentives to actually utilize the licensed spectrum in one way or another or sublicense it to another potential user (Mullane, 2009). The subsequent section provides and discusses such an example of unproductive spectrum (in a technical efficiency sense), before analytically examining two types of regulatory responses.

3. Allocative but not productive: property rights on 2.3 GHz

The 2.3 GHz band is one of the internationally popular bands for the deployment of the IEEE 802.16 standard (WiMAX). In Australia, the band consists of one huge, nation-wide spectrum space comprised between 2302 and 2400 MHz. Prior to 2000, the band was apparatus licensed (i.e. managed through a prescriptive ‘control and command' regime) and used for the transmission of text, images, sound, and entertainment video including terrestrial commercial television (pay TV). Following a price contest in 1994 (urban areas) and 1995 (rural areas), Austar United Communications (Austar), a leading provider of mainly digital satellite subscription TV services to rural Australia ended up holding

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6 The reason for the unusual size of the 2.3 GHz spectrum space is historical; the 2.3 GHz band was originally apparatus-licensed as fourteen 7 MHZ-wide television channels.
most licences\(^7\). Austar primarily used the licences to provide pay TV services although it is also a provider of internet and mobile telephony services. In January 2000, the Minister designated the band for spectrum licensing under section s.36 of the RCA 1992.

In January 2000, the Minister designated the band for spectrum licensing under section s.36 of the RCA 1992. Under section s.38 of the RCA 1992, the regulator then converted the B band\(^8\) 5-year Multipoint Distribution Stations (MDS) apparatus licences to 15-year spectrum licences by way of the Radiocommunications Spectrum Conversion Plan (2302-2400 MHz Band) 2000. This process effectively turned the band into leasehold private property, which allows the operation of any radiocommunications devices complying with the technical framework. As the conversion process preserved incumbency, the technical framework followed the assumption that the band would be used for MDS applications\(^9\). In 2005, Austar swapped its urban holdings of the 2.3 GHz licences for 3.6 GHz rural spectrum licences with Unwired, a wireless broadband carrier operating in metropolitan areas. Through the swap, Austar cashed in substantial capital gains and became the main holder of spectrum licences for the provision of rural WiMAX services.

The main economic issue with non-metropolitan spectrum licences in the 2.3 GHz band is band idleness. The 2.3 GHz spectrum licences are not being intensively used\(^10\), neither are they being subdivided, nor broken up, nor traded. As discussed above, unused spectrum is

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\(^7\) This earlier story is set out in the 26 June 2009 Austar submission to the DBCDE discussion paper on spectrum licence expiry (see http://www.dbcde.gov.au/consultation_and_submissions/).

\(^8\) The A-Band for MDS services is not related to the 2.3 GHz band. The A band used to span over 2076-2110 MHz and remained apparatus-licensed until the band was redesigned in 2002 by the Frequency band plan 2.1 GHz to accommodate fixed links (point to point services).

\(^9\) The technical framework introduced little change with respect to past MDS apparatus licences. The s.145 Unacceptable Levels of Interference (2302-2400 MHz Band) Determination 2000, issued for the conversion is only a simplified document declaring that all conditions of the licence must be complied with for device registration. The s.262 advisory guidelines merely followed the original Radiocommunications (Multipoint Distribution Station Licenses -- Regional Licences) Guidelines No.1 1995 issued in 1995 for apparatus-licensed MDS services in regional areas, retrieved from http://www.comlaw.gov.au/Details/C2004L05931.

\(^10\) Unwired has only deployed networks in Melbourne and Sydney (see the Unwired submission to the DBCDE paper retrieved from http://www.archive.dbcde.gov.au/2010/january/public_interest_criteria_for_re-issue_of_spectrum_licenses) and Austar has had some small scale deployments as well.
a matter of concern for regulators required to achieve technical (productive) efficiency, as is the case in Australia. It is also a matter of concern for a number of small regional operators and large national carriers with a high commercial interest in this spectrum. What then are the issues constraining service deployment in the 2.3 GHz band?

First, Austar has long stood by the promise of increased availability of WiMAX mobile equipments (mobile phones and WiMAX-embedded laptops), in order to use the band to provide broadband wireless access (BWA) services in rural areas. This expansion has been slowed by the commercial market rivalry between HSPA and WiMAX technologies and the strategic positioning of global manufacturers in this contest (Coutts 2008). These developments have raised uncertainty about the capacity of the WiMAX standard to extend beyond the mere provision of local wireless loops.

A second obstacle to service rollout is speculation over band value improvements (the option value problem). In this instance, the issue is not technological uncertainty, but expectations of future services that would help make the band profitable or more profitable. Recent years have seen increasing potential in the 2.3 GHz band for the deployment of wireless access services (WAS) using WiMAX technology. The WiMAX Forum listed the 2.3 GHz band as one of three globally harmonised bands suited to generating economies of scale in the production of WiMAX base stations (with specific emphasis on 2.3 GHz in the Asia-Pacific region). In October 2007, at the ITU's WRC07 congress, the ITU included WiMAX as its 6th terrestrial IMT-2000 radio interface standard\textsuperscript{11}, enabling spectrum owners to use equipments in a large range of countries. There are now strong expectations that the 2.3 GHz band will be set aside for WiMAX mobile broadband services in radio regulations decided at future WRCs. Accordingly,

\textsuperscript{11} For detailed specifications, see ITU-R M.1457 (rev.7) Recommendation (and subsequent revisions) retrieved from http://www.itu.int/rec/R-REC-M.1457/e
from 2008, the WiMAX Forum accelerated its certification process for its 2.3GHz mobile broadband profile culminating with the first certified profiles in June 2010. In turn, the certification of 2.3 GHz WiMAX profiles clears the way for ‘tri-band’ product certification, further adding to the array of potential services requiring access to the 2.3 GHz band.

Finally there has also been much uncertainty created by the government’s own policy announcements. The expected value of the 2.3 GHz band increased manifolds in 2006 after the Federal government flagged its intention to build a Broadband Connect Program - which would have to be wireless in rural areas for cost reasons. A highly profitable opportunity for the 2.3 GHz rural licences came in September 2007 when the OPEL consortium, jointly owned by Optus and Elders, won the government contract to roll out the wireless WiMAX broadband service by June 2009. The deal came with a government subsidy of $A950 million. Austar was part of rival consortium, Ausalliance, which failed to obtain government funding. Yet, Austar was now in a prime position to sell its highly demanded licences at an attractive price to OPEL and Optus did start negotiations with Austar. Eventually, the incumbent government lost the November 2007 elections, and both the OPEL contract and the Optus-Austar deal fell through. However, new speculative opportunities arose soon after for the owners of the 2.3 GHz band. The newly elected Labour government announced the launch of a National Broadband Network (NBN) aimed at covering 97% of the Australian population. Once again, the 2.3GHz licences could potentially play an important role in covering the wireless component of the NBN in regional Australia.

12 Tri-band (2.3, 2.5, and 3.5 GHz) certification aims at interoperability of mobile WiMAX products for global roaming across WiMAX networks.
13 Priced at $A 46bn. ($US 43bn. 09/2010), the NBN in Australia’s largest ever infrastructure project and will take many years to complete. The NBN will mainly consists of fibre, with between 5 and 10 percent of the network using wireless (for remote rural services).
As years went by, providers of wireless internet services to rural areas (WISPs) have been complaining that speculation activity is contrary to the spirit of spectrum licensing. WISPs claimed that Austar would not negotiate secondary access or third party operations with them. Austar on the other hand reported difficulties in agreeing to `reasonable commercial rates' to trade their spectrum with WISPs. In practice, the stalemate crowds out WISPs' services as there seems to be little bargaining space to negotiate access for their services. On the other hand, leasing various bits of its spectrum spaces to a multitude of WISPs may transform Austar's bands into a Swiss cheese, which may lower the band's value when the times come to negotiate a sale to the NBN Corporation. There were multiple sources of transaction costs for trading the 2.3 GHz licences: low net transaction gains and market fragmentation (dealing with multiple, small WISPs), legal constraints (defining secondary usage rights for short-term usage), and technological issues (probability of interference between WISPs and eventual WiMAX users). Thus, the unproductive use of the 2.3 GHz licences seemed to conform with the SPTF's somewhat prophetic words in 2002: ’high rates of spectrum and technical efficiency may just be too costly to achieve compared to the benefits they create to society as a whole'.

Yet, this situation is perplexing regulators. First, regulatory agencies serve governments. Governments are constrained by short-term political cycles and the relative urgency to deliver visible and tangible results for their constituencies. This is particularly true in Australia where political cycles are very short (3 years or less). From this perspective, critical resources left idle create tensions. Second, what serves the public interest better: productive or dynamic (allocative) efficiency? Are the outlined benefits foregone by preventing a Swiss cheese approach higher or lower than the net discounted benefits.

14 Austar's views on this and other matters related to the use of the 2.3GHz band can be consulted in their 26 June 2009 submission to DBCDE retrieved from: http://www.archive.dbcde.gov.au/__data/assets/pdf_file/0005/118364/AUSTAR_submission_25_Jun_09.pdf
(inclusive of opportunity costs) of keeping the spectrum fallow? If the market mechanism can be trusted, it would suggest that if Austar holds on to their spectrum rather than trade it with WISPs, it must imply that the net discounted value of the current and future benefits from trading are lower than the expected benefits from speculating. But, speculative behaviour may also involve reckless games of brinkmanship, which may not serve the public interest at all. The wasted opportunities to use the band productively before, while and after the OPEL joint venture collapsed provide enough evidence that spectrum owners may fail to allocate spectrum to any productive usage for significant amounts of time. The future benefits that would justify such strategic behaviour may take a long time to accrue, or may fail to do so altogether. On the other hand, amending the Radiocommunications Act 1992 to forbid speculation considerably reduces the property rights (and hence the value) of spectrum licences. As has been stressed by many economists, speculative behaviour may make perfect economic sense and help channel spectrum to its most valued usage, depending on the circumstances (Rosston & Steinberg, 1997; Productivity Commission, 2002; Cave, 2010).

The story of the non-metropolitan 2.3 GHz licences thus illustrates a conflict between goals of allocative and productive efficiency for large nation-wide communications networks. The matter is typically complex, combining issues of exclusive rights, band idleness, speculative rather than productive usage, and uncertainty about license renewal. However, this example also suggests that a `use it or lose it' approach by regulators (emphasizing goals of productive efficiency over other efficiency objectives) could undermine confidence in the acquired property rights of spectrum owners, and could distort the nature of long-term regulatory decisions.
Epilogue - In November 2009 Austar announced that alongside Unwired (the owner of the metropolitan 2.3 GHz licences) it will lease some of its 2.3 GHz spectrum to utility provider SP AusNet, who will use the spectrum for ‘smart grid’ metering. Although this trade came unexpectedly after years of inactivity, its characteristics are consistent with the predictions of several market commentators, such as Xavier and Ypsilanti (2006) and Akalu (2010), who both stress that spectrum trading is more likely to happen when interdependency amongst users is low (in terms of likely interferences, technical parameters, regulatory rights, contract terms, etc.). Contrary to WISPs, SP AusNet will use the spectrum to build a WiMAX network (albeit for telemetric rather broadband services), which ensures technological compatibility with the long-term goals of Austar. Contrary to the multitude of WISPs, SP AusNet is also a single party and, with 680,000 customers to serve, a rather important market player as well. Intuitively, spectrum trading became more attractive because the net transaction gains were higher. In particular, the transaction costs of dealing with a single, technology-compatible lessee were much lower than for WISPs: a common network technology lowers the probability of interference, and dealing with a single but large lessee considerably reduces costs of information, legal services and regulatory compliance.

4. Approaches to enhancing efficiency in spectrum use

The narrative from the previous section strongly suggests that the conflict between technical and allocative efficiency in spectrum use arises primarily from the presence of transaction costs in secondary markets for spectrum\(^{15}\). The fact that license holders have a strong incentive to maximize their private value of spectrum implies that in the absence of

\(^{15}\) It may also be that no transaction took place earlier because Austar’s potential business partners would not have had a business case for a short-run service. A short-run service would have allowed Austar to continue speculation without concern for future ‘use it or lose it’ measures, but, it may be that given the current costs of radio transmission, equipment and consumer expectations, no WISPs would wish to acquire such a licence.
transaction costs they would put their scarce spectrum to productive use. In such a world, the market mechanism would simultaneously achieve technical and allocative efficiency. However, the presence of transaction costs makes regulatory intervention necessary to alleviate inefficiencies in the use of spectrum.

Several approaches to dealing with this problem have taken increasing prominence over time. The first approach consists of implementing a set of policies aimed at facilitating spectrum trading in secondary markets and there is an emerging literature on this subject (Valletti, 2001; Hazlett, 2003; FCC, 2004; OFCOM, 2004; Peha & Panichpapiboon, 2004; Xavier & Ypsilanti, 2006; ACMA, 2008; Crocioni, 2009; Bykowsky, Olson & Sharkey, 2010; Mayo & Wallsten, 2010). For example, Mayo and Wallsten (2010) most recently describe a number of steps taken by the FCC to facilitate secondary spectrum trading in the US, including establishing a comprehensive database of all transactions taking place in the secondary markets and devising several standardized versions of licensing agreements. They note that these policies have significantly simplified spectrum trading and lead to the emergence of a viable secondary market in spectrum rights. Other countries such as Australia and the United Kingdom have taken similar approaches but results have been less encouraging than in the US for several bands (ACMA, 2008; Akalu, 2010), including the 2.3 GHz band discussed in the previous section.

The second approach to dealing with non-use of spectrum focuses exclusively on the technical efficiency side by implementing some form of administrative restriction on licensees' rights not to use their allocated spectrum. These restrictions usually take the form of 'use it or lose it' provisions, which state that a spectrum license can be revoked if the service rollout does not take place within a specified timeframe. The United States,

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16 In Australia, for instance, the ACMA maintains a register of existing licenses and all secondary market licensing agreements
New Zealand and several European countries (e.g. The UK, Denmark, Sweden and France) have been implementing ‘use it or lose it' provisions over the years. For instance, many 3G auctions (in the US, UK, Denmark, etc.) in the period 1999-2000 required minimal network coverage within the first 2 years of the license. The United Kingdom's auction in November 2000 of 28GHz licenses for broadband fixed wireless access services included ‘use it or lose it' requirements to roll-out networks with a minimum 10% coverage of the licence's specified region within less than 2 years. The Cave Review (Cave, 2002) effectively marked the end of ‘use it or lose it' provisions in the UK. However, other countries still impose ‘use it or lose it' clauses. In May 2007, New Zealand auctioned its 2.3 and 2.5 GHz licences with similar provisions attached. In its 2010 overview of the spectrum licensing framework, the Independent Communications Authority of South Africa (ICASA) states that spectrum licenses for highly demanded frequency bands will feature ‘use it or lose it' clauses setting minimum roll-out targets to be achieved within the first two years of licence issual. If the licensee fails to meet at least 50% of the rollout targets, the ICASA is required to withdraw the license. Other countries, such as Australia, have since shown interest in applying such policies in their spectrum licensing contracts.17

In sharp contrast to policies attempting to facilitate secondary spectrum trading by reducing transaction costs, administrative mandates such as ‘use it or lose it' clauses do not use up much real resources and thus might appear as a cost-effective way to enhance efficiency. However, these clauses create other types of social costs by interfering with the firm's ability to maximize the option value of a spectrum license (Cave, 2002). In addition,

17 Use it or lose it' clauses are not allowed under the Radiocommunications Act 1992, but Australia has conducted consultations for possible amendments to the Act allowing past usage to be a criterion of license renewal (DBCDE, 2009). Major stakeholders such as the Telstra Corporation and the Australian Broadcasting Corporation are in favour of adopting such provisions. However, it is fair to say that Australian regulatory authorities are lukewarm towards 'use it or lose it' clauses and there has been no marked progress in that area since then
it would be difficult under this approach to distinguish between `strategic' episodic utilisation and genuine spectrum utilisation (Cave, 2010).

Why then so much regulatory interest for this approach? Perhaps this is due to a fundamental mismatch between the optimal timing horizons of regulators and network operators, driven primarily by the presence of transaction costs or lack of profitable use. Regulatory agencies have to respond to the pressures of short-term political cycles. They need to produce relatively quick and tangible outcomes (such as a visible productive usage of spectrum) in order to satisfy the needs of constituencies and generate political gains. Furthermore, they are also subject to lobbying from competing users with an interest in the under-used spectrum. Network operators, by contrast, make long-term decisions that weigh the risk involved in rolling out a network while technology is still changing (e.g. the risk of a short-term infrastructure write-down) and the opportunities offered by future alternative uses of the spectrum. Not using the spectrum due to long-term considerations is not a source of inefficiency. Of course, operators' decisions may also be inefficient for society if the purpose of acquiring the licences and not using them is to discourage competition. Yet, fundamentally, there is divergent optimal timing horizon between public actors and private operators.

Although optimal timing and political economy issues are beyond the scope of this paper, a careful understanding of the trade-off between the two approaches is best analysed through a formal model of licensee incentives with and without `use it or lose it' obligations. The next section presents such a model and uses it to shed light on the optimality of the various government policies directed at increasing efficiency of spectrum use.

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18 Cave (2010) provides an interesting analogy with airport slot utilisation at highly congested Heathrow airport. Since slots are not guaranteed to airliners making less than 80% usage, many companies run fictitious or half-empty flights just to meet usage targets.
5. A Model of ‘use it or lose it’ provision in spectrum licensing

5.1. Model setup

Consider a firm (a licensee) holding a spectrum licence, which for simplicity is assumed to be of infinite duration. This firm faces the following investment decision: it can invest in one of two mutually exclusive projects (e.g. roll out one of the two services):

- Project 1: is a ‘safe’ project with known return (net present value) \( V_1 = V_S \).
- Project 2: is a ‘risky’ project with unknown return \( V_2 \), which can take two possible values \( V_H \) and \( V_L \), with \( V_H > V_L \).

The licensee’s prior beliefs about the probability of each outcome if the risky project is undertaken are given by \( P(V_2 = V_H) = \pi \) and \( P(V_2 = V_L) = 1 - \pi \). To make the model interesting, further assume that \( V_H > V_S > V_L \) and that if the firm had to implement a project immediately at the start of the licensing period it would choose the safe project, \( V_S > \pi V_H + (1 - \pi) V_L \). In many cases, it is reasonable to assume that uncertainty about the value of project 2 will be resolved with the passage of time. For example, at the start of the licensing period it may not be clear which technical standard will eventually prevail in a given market. In such cases, it might be optimal for the firm to pursue a ‘wait and see’ strategy by waiting for the uncertainty to be resolved and then implementing the most profitable project. The option value of waiting before committing to an investment project is reflected in the firm’s willingness to pay for the licence (and hence affects government revenue).

Suppose that the firm may learn the value of project 2 with probability \( p > 0 \), which is exogenous and does not depend on firm’s actions. Waiting on the other hand is costly.
because the firm discounts future returns at rate $\delta \in (0, 1)$. In this setting, the firm faces two possible strategies:

- **Strategy 1:** Invest in Project 1 immediately and obtain payoff $S_V$.

- **Strategy 2:** Wait until the uncertainty about the risky project is resolved and invest in the project with the highest ex post return.

Let $\Pi_i = V_s$ denote the payoff from strategy 1. To compute the payoff from strategy 2, note that because $p$ does not change with time, if the firm finds it optimal to wait in period 1 then it is also optimal to wait in all subsequent periods. Note also that because $V_H > V_S > V_L$ after the uncertainty is resolved the firm will invest in Project 2 if and only if $V_2 = V_H$. Finally assume that if uncertainty is resolved in period $t$ then the optimal project can be implemented in period $t+1$. Thus, the payoff from strategy 2 is given by:

$$
\Pi_w = p\delta[\pi V_H + (1-\pi)V_s] + (1-p)p\delta^2[\pi V_H + (1-\pi)V_s] + (1-p)^2 p\delta^3[\pi V_H + (1-\pi)V_s] + \sum_{t=3}^{\infty} (1-p)^t p\delta^{t+1}[\pi V_H + (1-\pi)V_s]
$$

(1)

With probability $p$ the uncertainty about project 2 is resolved in period 1 and the firm can implement the project with the highest payoff ($V_H$ or $V_S$) starting from the next period.

With probability $p(1-p)$ the uncertainty is resolved in the second period, and so forth.

Note that because $(1-p)\delta < 1$ the payoff from strategy 2 can be reformulated as:

$$
\Pi_w = \sum_{t=0}^{\infty} (1-p)^t \delta^{t+1} p[\pi V_H + (1-\pi)V_s] = \frac{p\delta[\pi V_H + (1-\pi)V_s]}{1-(1-p)\delta}
$$

(2)

The wait-and-see strategy will be chosen by the licensee if and only if $\Pi_w \geq \Pi_i$, that is if:
\[ \frac{p \delta \pi V_H + (1 - \pi)V_S}{1 - (1 - p)\delta} \geq V_s \]  
(3)

which is equivalent to:

\[ \frac{V_H - V_s}{V_s} \geq \frac{1 - \delta}{\pi p \delta} \]  
(4)

Intuitively for given values of \( V_H \) and \( V_s \), the wait-and-see strategy is more likely to be optimal if the time discount rate is low, and if the probability that uncertainty will be resolved in a given period is relatively large. It is also important to note that as long as the firm's payoff coincides with the social value of each project the firm's decision will maximize social welfare.

### 5.2. Secondary markets for spectrum

The fact that the licensed spectrum remains unused for some length of time if the firm chooses to pursue a wait-and-see strategy creates the conflict between technical and allocative efficiency considerations. While it might be socially optimal to wait until the uncertainty is resolved, technical (productive) efficiency is not achieved during the waiting period. As the discussion of the 2.3 GHz licences illustrates, in such situations regulators might face pressure from various stakeholders to implement a policy addressing the lack of technical efficiency in spectrum use. However, it is important to recognize that the existence of socially valuable alternative uses of the spectrum during the waiting period constitutes an additional profit opportunity for the firm. For example suppose that the secondary use of the resource results in a social return \( v > 0 \) per period and that the present value of this secondary use is lower than the social value of the safe project, i.e.,
Suppose further that the private return to licensees from employing spectrum for secondary use is given by \( v_p \), with \( v \geq v_p > 0 \). Then regardless of how small the value of \( v_p \) is, the firm will always choose to employ spectrum for secondary use while waiting for future opportunities to arise - because such a strategy increases the overall payoff from the wait-and-see strategy.

This observation suggests that non-use patterns in the context of this model must respond to some form of transaction costs preventing the licence holder from employing the spectrum for secondary use and achieving the degree of technical efficiency required by legislation. As discussed in the case of the 2.3 GHz licences above these transaction costs might arise due to the necessity to negotiate with other parties who have an interest in some alternative use of the spectrum. To capture this idea, assume that during the waiting period the primary licence holder can lease (i.e. `sub-license`) the spectrum to secondary users and obtain a per-period payoff \( v_p \). When the uncertainty about project payoffs is resolved, the licensee will want to terminate these leases in order to implement the project with the largest payoff. In order to terminate secondary leases the licensee must incur some transaction cost \( c > 0 \). A regulatory authority could reduce this termination cost by introducing standardized licensing contracts or other measures, which facilitate the development of a secondary market for the spectrum.

This additional licensing opportunity provides the firm with another strategy it can pursue in addition to investing outright or simply waiting for the uncertainty to be resolved:

- **Strategy 3: Lease-and-wait** until the uncertainty about the risky project is resolved and then implement the optimal project.
Assuming that license termination occurs at the end of the period over which uncertainty is resolved and the firm implements the optimal project starting from the next period, the payoff from the lease-and-wait strategy is given by:

\[
\Pi_{LW} = v_p + p[\delta [\pi V_H + (1 - \pi)V_S] - c] \\
+ (1 - p)\delta (v_p + p[\delta [\pi V_H + (1 - \pi)V_S] - c]) \\
+ \sum_{t=2}^{\infty} (1 - p)^t \delta^t (v_p + p[\delta [\pi V_H + (1 - \pi)V_S] - c])
\]

(5)

In the first period, the firm will get lease revenue \(v_p\) and with probability \(p\) uncertainty will be resolved in which case the licensee will pay the termination cost and obtain the payoff from implementing the most profitable project in the next period. With probability \((1 - p)\) the payoff of the risky project remains uncertain in period 1, in which case the licensee will again obtain licensing revenue \(v_p\), etc.

The payoff from the lease-and-wait strategy is now given by:

\[
\Pi_{LW} = \sum_{t=0}^{\infty} (1 - p)^t \delta^t (v_p - pc + p\delta [\pi V_H + (1 - \pi)V_S])
\]

\[
= \frac{v_p - pc + p\delta [\pi V_H + (1 - \pi)V_S]}{1 - (1 - p)\delta}
\]

(6)

Note that the licensee will prefer to lease the spectrum rather than simply wait when \(v_p > pc\), that is when the per period payoff from licensing exceeds its expected cost. To conclude, the optimal strategy is:

- Strategy 1 if: \(\Pi_I > \max\{\Pi_{W}, \Pi_{LW}\}\)  \hspace{1cm} (7)
- Strategy 2 if: \(\Pi_{W} > \max\{\Pi_I, \Pi_{LW}\}\)  \hspace{1cm} (8)
- Strategy 3 if: \(\Pi_{LW} > \max\{\Pi_I, \Pi_{W}\}\)  \hspace{1cm} (9)
Note that if the licensee is able to extract the full social value of the secondary use of spectrum, i.e. if $v_p = v$, then social welfare is equal to firms' expected profit and there is no rationale for government intervention except for the purpose of reducing transaction costs. However, when the social and private values of the secondary use of the spectrum diverge, it might be the case that secondary leases are more efficient from a social but not from a private point of view. In particular, this will be the case if the social value but not the private value of the secondary use exceeds the expected per-period cost of leasing the spectrum, i.e. when $v > pc > v_p$. Such a situation would warrant regulatory intervention through administrative measures designed to improve the technical efficiency of the market.

5.3. Analysis with ‘use it or lose it’ provision

Consider now an administrative mandate, which aims at achieving technical efficiency in the use of spectrum by imposing a `use it or lose it' clause. Such clauses typically stipulate that a spectrum licence be revoked if the spectrum remains unused by a specified date and/or if network deployment has not reached a minimal coverage benchmark. To simplify the analysis, assume that the government issues a mandate, which requires the spectrum to be in use at all times starting from period 1 (the qualitative conclusions, which follow from this assumption would remain unchanged in a more general setup with a phase-in period).

In this model introducing `use it or lose it' requirements is equivalent to eliminating the wait-and-see-then-invest strategy from the list of strategy options. Imposing this constraint thus affects the firm's decision only for the case where the wait-and-see strategy is optimal, that is when $\Pi_w > \max\{\Pi_i, \Pi_{IW}\}$. In this case, $pc > v_p$ and the firm would prefer
waiting-and-seeing to leasing-and-waiting. If waiting-and-seeing is no longer an option the firm must either implement the safe project, if \( \Pi_I > \Pi_{LW} \), or lease-and-wait otherwise.

To understand the economic implications of `use it or lose it' provisions, note that such policy will increase social welfare when both \( v > p_c > v_p \) and \( \Pi_{LW} \geq \Pi_I \) are true. In this case the firm will optimally choose to lease-and-wait and it will be socially efficient because \( v > p_c \). On the other hand, if \( v > p_c > v_p \) and \( \Pi_I > \Pi_{LW} \) then `use it or lose it' provisions reduce social welfare. To see why, note that `use it or lose it' provisions have an impact on the firm's decision only when \( \Pi_{W} > \max\{\Pi_I, \Pi_{LW}\} \).

Thus, when the inequality \( \Pi_{W} > \Pi_I > \Pi_{LW} \) holds introducing these constraining provisions induces the firm to invest from the outset in the safe project to satisfy the technical efficiency requirement. However, waiting would be preferable from the social point of view because \( \Pi_{W} > \Pi_I \) and because the firm fully internalizes the social returns from its investment projects. It can therefore be concluded that implementation of `use it or lose it' provisions will have an ambiguous effect on social welfare: it will increase welfare if the lease-and-wait strategy is preferred to investing in the safe project, and will reduce efficiency otherwise. In addition to these conclusions, it is also easy to see that introducing `use it or lose it' provisions will decrease the firm's willingness to pay for the spectrum licence, which has a negative impact on government revenue.

Naturally, none of the shortcomings of the `use it or lose it' approach applies to the alternative strategy of reducing transaction costs in the secondary market for spectrum. In particular, when \( v > p_c > v_p \) the reduction of the value of \( c \) simply makes the lease-and-wait strategy more attractive compared to the strategy of simply waiting until uncertainty
about the risky project payoffs is resolved. Reduction in transaction costs will also increase firms’ willingness to pay for the license in the first place, thus increasing government revenue. The model studied in this section therefore implies that while ULP has an ambiguous effect on social welfare, reduction in transaction costs is always welfare improving. And so, it is reasonable to conclude that instead of pursuing administrative measures, which might have unintended adverse effects on social welfare, regulators should concentrate their efforts on developing viable secondary markets for spectrum, which has an unambiguous positive effect on both technical and allocative efficiency.

6. Conclusion

This article started with two questions; what are the efficiency objectives of spectrum policy reforms and how should decision makers rank them when they conflict with one another? This study presented and analysed an example illustrating the trade-offs involved between different efficiency objectives. In an Australian context (but with clear implications for other reforming economies) this example showed that a property rights approach to spectrum governance may lead to allocative- but not productive-efficient solutions. This situation in turn makes life difficult for regulatory agencies, which are accountable to legislative authorities for efficient spectrum usage. There is no shortage of solutions to this problem: strip non-using owners of their exclusive rights under ‘use it or lose it’ clauses, or redefine property rights so that secondary users can access the spectrum when the primary user does not use it.

Yet, economists would strongly disagree with any of these approaches. The apparent low usage of spectrum bands by some owners who paid a high price for the rights to use them can only make economic sense if one accounts for unobserved maximising behaviour. As the paper illustrates, owners of unused spectrum may very well maximise the expected
value of their resource over a finite time horizon. By the very uncertain nature of multi-period profit optimisation, these decisions may fail to deliver the right outcomes to their owners ex post, but the decisions remain nonetheless optimal ex ante and perfectly coherent with rational expected behaviour on the part of firms / licensees.

This argument was formalized in a model of a firm's decision-making in the presence of uncertainty about future payoffs and used this model to study the effects of use it or lose it clauses on firm's behaviour and social welfare. The main claim of the paper is that use it or lose it provisions will do little to alleviate inefficiencies in spectrum use if these inefficiencies are driven primarily by the presence of transaction costs in secondary markets, as appears to be the case in many situations. Therefore, the focus of regulatory policy should instead rest squarely on reducing these transaction costs and creating transparent secondary spectrum markets.

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