Spectrum and the Wider Economy[1]

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1. Introduction

Spectrum management used to be an esoteric specialism practised mainly by engineers outside the knowledge and understanding of policy makers, businesses and consumers. That all changed with the rapid diffusion of mobile communications in the 1990s, and the consequential rocketing in the values of spectrum, vividly illustrated in the auctions of 3G spectrum around 2000. Since that time, spectrum management has risen in importance and, as part of this process attention has been directed to the growing role of spectrum-using services in the economy and society.

In the case of some natural resources, calculations of the level of economic activity they add to the economy are justified by the possible exhaustion of supply. In the case of spectrum, this is not an imminent or even a distant prospect. However, estimates of the growing importance of spectrum-using services do underline the importance of allocating what we have efficiently. Thus if misallocation and hoarding reduce the effective stock of spectrum by one half, a quick and inexpensive way of increasing output and welfare in the economy is to improve the spectrum management regime.

This chapter brings together some estimates of the links between the use of spectrum and the wider economy. The focus is not on spectrum itself (as this is an input) but on the spectrum-using services which generate final output. We first consider how key services which rely on spectrum contribute to economic welfare; examine the weight of those services in gross domestic product, or GDP; and consider evidence on how investment in information and communications technologies (ICT) has contributed to increasing productivity throughout the economy.

However, the impact of certain spectrum-using technologies, notably mobile voice and data communications, has the potential to pervade the economy, not only affecting firms and households directly purchasing spectrum-using services, but changing business models, altering competitive structures and promoting innovation. Attempts have been made to estimate these external effects by relating changes in GDP to the diffusion of fixed and mobile communications services. We discuss the implications of these results.

2. Spectrum, spectrum-using services and their impact on welfare

A standard way of assessing the contribution of spectrum and spectrum-using services to economic welfare is to establish the contribution to economic welfare which they

[1] From M Cave and W Webb, *Using Spectrum*, Cambridge University Press, forthcoming. Please do not circulate more widely.

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make. This can be done using a standard technique of economic analysis illustrated in Figure 1, which presents an application to mobile voice calls.

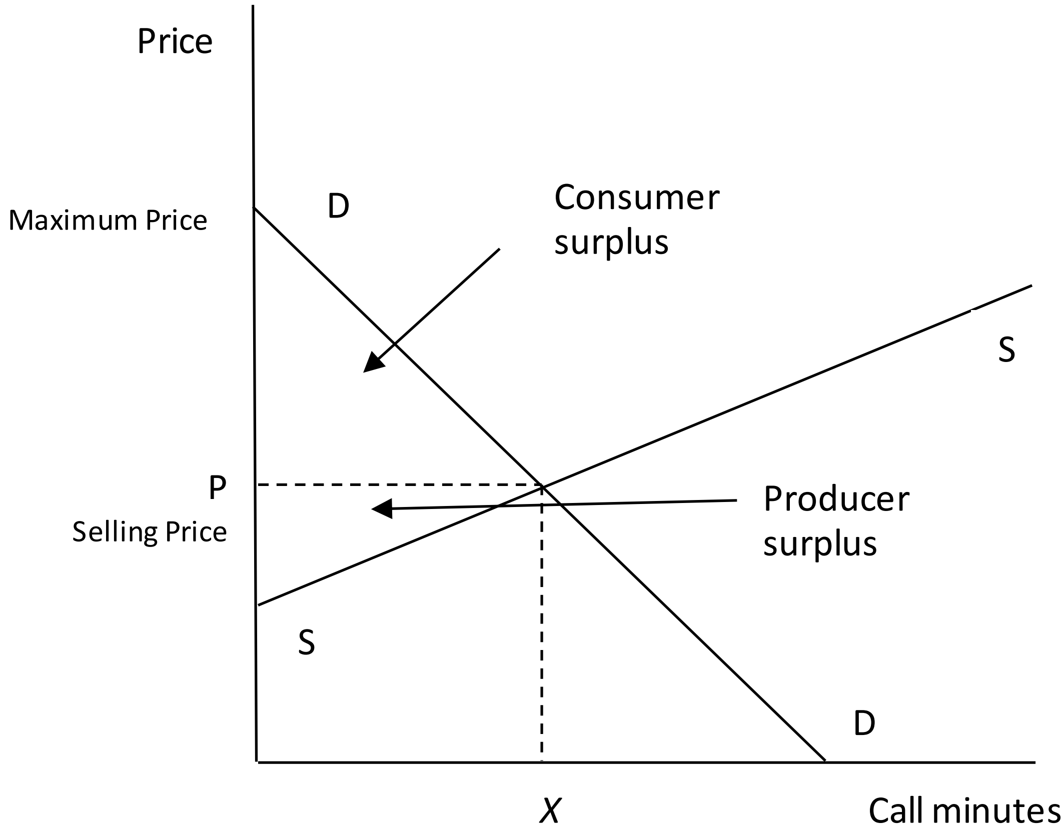

Figure 1 – The consumer and producer surplus generated by a spectrum-using activity

The curve marked DD is the demand curve for calls in the country in question. Its downward slope reflects the fact that as price falls, the demand for calls increases. It is important for what follows that the demand curve intersects the vertical axis at what can be called the 'maximum price'. This is the price at which demand goes to zero or is choked off – also called the 'choke price.'

The supply curve (SS) represents the number of call minutes which the mobile operators would jointly produce at different prices. Its upward curve can reflect the fact that if the price per minute rises, operators will increase supply, for example building out their networks into more sparsely populated and costly areas.

The equilibrium of this market occurs at a 'selling price' of P and a quantity of call minutes of X.

Now consider the triangle marked 'consumer surplus.' This area arises because the caller values the first minute of calls purchased at a maximum price, which is considerably in excess of the selling price. That consumer is therefore getting a benefit or surplus in excess of the price paid. That surplus diminishes down the demand curve as the quantity purchased rises to X, reaching zero at X itself. Total consumer surplus can therefore be estimated as the area shown, which on these facts, because the demand curve is linear, is a triangle.[3] The procedure requires that there is a maximum price - if the demand curve never met the vertical axis, the area of consumer surplus would not be defined.

Parallel to consumer surplus, there is a benefit to producers known as producer surplus, also shown in figure 1. The shape of the supply curve reflects the marginal costs which mobile operators collectively incur in supplying call minutes. Its upward slope can be thought of as reflecting rising additional costs incurred in supplying further call minutes.

As a result of this shape, producers of some calls find themselves being able to sell units at a price (the selling price) which exceeds their marginal costs of production. This is not necessarily pure profit, as some of it may be spent on costs which do not vary with output – the cost of a mobile licence for example. It is more what accountants call a 'contribution,' or revenue in excess of variable costs.

There is disagreement over whether economic welfare should include consumer surplus alone, or should be the sum of consumer and producer surplus; underlying this issue is a question of whether the profits from businesses should count as contributing to welfare.[4] Some of the welfare measures reported below are of consumer surplus alone; some also include producer surplus.

It makes sense in the case of services which depend crucially upon spectrum as an input to ascribe the surplus (however defined) to spectrum. This applies in the case of mobile communications, which cannot operate without spectrum as an input. It makes less sense in the case of services where spectrum plays a subordinate or even a dispensable role. Accordingly calculations of spectrum-related welfare typically concentrate on a limited number of particular activities.

As an example of calculations of this kind, in 2012 the UK government commissioned Analysys Mason, a consultancy, to conduct a study which estimated the welfare effects of seven notable spectrum-using sectors in 2006 and in 2011. The results are given in table 1.

	2011 value (£billion)	Real increase 2006-2011 (%)
Public mobile communications	30.2	16%
Wi-Fi	1.8	N/A
TV broadcasting	7.7	79%
Radio Broadcasting	3.1	35%
Microwave links	3.3	-29%
Satellite links	3.6	7%
Private mobile radio	2.3	25%
TOTAL	52.0	25%

Table 1 - Welfare effects (consumer and producer surplus) of seven spectrum using services

[3] The expression for the area of a right-angled triangle is: ½ x h(eight) x b(ase). If the demand curve were non –linear, the area could be estimated using a different formula.
[4] This is a hotly existed issue but we do not consider it here now.

Source: Department for Business, Innovation and Skills (BIS), Department for Culture, Media and Sport (DCMS) and Analysys Mason (2012), "Impact of radio spectrum on the UK economy and factors influencing future spectrum demand",

The 2011 figure as a percentage of GDP is 3.4%.[5] 80% of the benefit comes in the form of consumer surplus, the remainder as producer surplus.

3. Effects of spectrum-using services on GDP and employment

An alternative measure is via the contribution to national income, output or product made by spectrum- using sectors. Gross Domestic Product is found by adding together the value added (revenues minus material inputs) of all the sectors in the economy. It is also a measure of the income available for distribution to factors of production - labour, capital and natural resources, including spectrum. It is therefore possible to gather data on value added in chosen spectrum-using sectors and aggregate it to produce an overall figure of direct contribution to GDP.

As before this procedure makes more sense in application to activities which rely in some fundamental and unavoidable way on spectrum, rather than in cases where the role of spectrum as an input is small or contingent.

This 'direct' measure only captures the immediate effect on Gross Domestic Product of the chosen spectrum-using sectors. But spectrum's impact on production is felt not only in mobile communications but also in activities such as the manufacture of smart phones and the construction of towers to support antennae. The calculation can thus be extended to include these indirect effects. The direct and the overall (direct and indirect) impacts of spectrum on job creation can also be estimated from employment data by sector.

These calculations are illustrated in a 2013 study by Deloitte and Access Economics of the impact on GDP and employment in the Australian economy of the mobile sector in 2009-10 to 2011-2012. Both the direct and overall contributions the direct plus indirect contributions were computed. The results are shown in table 2.

	A$ (bn)	000's	% of GDP	% of employment
Values				
Direct contribution	7.8		0.5	
Total contribution	14.1		0.9	
Employment				
Direct effect		22.3		0.2
Total effect		56.9		0.5

Table 2 - The direct and total contribution of mobile to the Australian economy in 2011-12. [Source: Australian Mobile Telecommunications Association (AMTA) [1].]

[5] This figure is given just as an indication of scale, as data on consumer and producer surplus uses a different metric than that used for GDP, which is described in the next section.

4. Effects of spectrum-using services on productivity

A further extension of the above-noted analysis of indirect effects takes us into the territory of how a spectrum-using service such as mobile communications might increase productivity when it is used not as a consumer service but as an input in another sector of production. This calculation is of interest as a component of the long-running debate about the impact on productivity of information and communications technologies (ICT).

This began with the famous ‘Solow paradox’, the observation in 1987 by Robert Solow [2] that ‘you can see the computer age everywhere but in the productivity statistics."Various explanations for this paradox were identified. Whatever the explanation, later studies in ‘growth accounting’ (breaking down productivity changes into components attributable to labour inputs, capital inputs and technical progress) demonstrated a much greater effect. Thus a study by Jorgenson et al. [3] concluded that ICT was responsible for 50% of US labour productivity growth between 1995 and 2000 and 33% between 2000 and 2005. Timmer and van Ark [4] concluded that higher ICT investment explains more than half the US advantage over Europe in labour productivity growth from 1995 to 2001. A recent review of the empirical literature concludes that the productivity effect of ICT is significant, positive and increasing, with the US/Europe differential found in aggregate, but this may be due to lower levels of ICT investment in Europe.[5, p. 117].

Breaking down the impact of ICT into the contributions of its components such as mobile communications presents enormous problems, especially if the different ICT inputs, notably information processing and communications, are complementary, as has been suggested. There is however a more direct way of establishing the effect on the economy of communications, and mobile communications in particular, to which we now turn.

5. Estimating the macroeconomic effects of the diffusion of communications services, including mobile communications

One of the debates about ICT focuses upon whether it is a ‘general purpose technology’ or an ‘enabling’ technology with the characteristic that it affects a multitude of economic activities, all of which it makes more productive.[6] This opens up the possibility that it can have considerable ‘spillover effects’ throughout the whole economy, which are not captured by the analyses described above. Since our focus is a narrower one on spectrum use, it is not necessary to decide this broader question relating to ICT as a whole.

In relation to broadband it is a common and everyday observation that few acts of consumption and production by those with access to broadband are wholly immune from its effects on their lives. In 2013, three quarters of those connected to broadband were using a mobile connection, and this proportion will rise further as broadband

[6] The standard precursor of ICT as a general purpose technology is electricity. See [6,7].

connections grow in the less developed world which has much more limited access to fixed networks [8].

Since then a process of enumeration of wider effects of broadband has taken place. A typical classification includes the following:

- enhanced speed and quality of information flows: sometimes it is suggested that the combination of more information processing and faster communications are necessary to deliver the benefits, with one alone producing less spectacular results;
- better access to markets: due to lower barriers to entry, an increase in the geographical scope of markets (the 'death of distance'), better job matching, better access to customers via the web etc.;[7]
- new business processes and organisational structures: better stock control, quicker contracting, just-in-time production etc. (For example, a large grocery company operates in the US and in several Latin American countries. It is reported that the lack of reliable broadband in one of the Latin American countries leads to an entirely different approach to logistics than is applied in the USA.);
- more innovation in general: made possible by the availability of new communications services; examples can be multiplied – social networks being a particularly significant one.

This is a plausible story, and some effort has gone into testing it. One strategy would be to try to identify the impact of mobile voice and broadband application sectors, and aggregate them. This would be very complex and the results inevitably contestable. An alternative is to adopt a cross-section approach: to collect data on the diffusion of voice and broadband services in a sample of countries, and test the hypothesis that higher diffusion rates are associated with higher levels of GDP.

The method is more complicated when the sample includes countries some of which rely virtually exclusively on wireless networks and others where both fixed and wireless voice and data services are available. In the latter case, for our purpose some partitioning of effects between spectrum-using and non spectrum-using services is required.

The simple *modus operandi* of such studies is illustrated by an influential 2009 World Bank study of developing countries [10]. It involved estimating the following regression equation:

> 'The average growth rate of per capita GDP between 1980 and 2006 was used as the dependent variable and regressed onto the following variables, selected as representative of conditioning variables in the growth literature:
> • Per capita GDP in 1980;
> • Average ratio of investment to GDP between 1980 and 2006
> • Primary school enrolment rate in 1980 (a proxy for human capital stock)

[7] For an illustration of how this takes effect with voice communications, see the study by Jensen [9] describing how fishing vessels in South India, before landing their catch, can call the shore to establish in which port the best prices can be found.

• Average penetration of broadband and other telecommunications services between 1980 and 2006 for developed and developing countries (a proxy for technological progress and the focus of the analysis);
• Dummy variables for countries in the Sub-Saharan Africa, Latin America and Caribbean Regions.'

The problem with this procedure is that it does not unpack the rather complex two way supply and demand interactions which take place between a sector and the macro-economy. Other studies use more sophisticated structural models, but, as shown below, the range of results is very wide.

Waverman et al. [11] led the way with an analysis of the mobile sector, which suggested that differences in mobile voice diffusion accounted for a significant part of GDP differences across a wide variety of countries. A later study of this technology by Gruber and Koutroumpis [12] found a significantly smaller effect.

Similar studies have been done of the impact on growth of a 10% increase in the diffusion of broadband. A summary of some recent results is shown in
Table 3.

Authors	**Countries**	**Effect on growth of 10% additional broadband penetration**
Czernich *et al.*	OECD, 1996-2007	0.9-1.5%
Katz &Avila	24 Latin American and Caribbean countries	0.2%
Gruber & Koutroumpis	EU15, 2003-2006	0.26-0.38%
OECD	EU countries, 1980-2009	1.1%

Table 3. Estimates of the effect on growth of increased penetration.

The results of the above-noted World Bank study are shown in Table 4.

% increase in economic growth per 10% increase in penetration, in:	**Fixed**	**Mobile**	**Internet**	**Broadband**
High income countries	0.4	0.6	0.8	1.2
Low income countries	0.7	0.8	1.1	1.4

Table 4. Estimates of the effect on growth of increased penetration of telecommunications services. Source: [10].

If these results were confirmed as applying exactly to a country which started from a zero base of broadband penetration, and achieved an annual increase in broadband penetration of 10% per year for ten years, then that country's GDP would grow 1.2% faster than it would otherwise in each of those ten years. However, a number of problems of interpretation arise in connection with these results.

- The samples of countries in some studies are fairly heterogeneous, with respect to income per head and endowment of fixed networks. In some countries, effectively all broadband is wireless. In others, mobile broadband has been superimposed upon widely diffused fixed broadband services. This is likely to influence patterns of use, as between, say, consumption and productive uses;
- As noted, most studies to date have focussed on fixed broadband, whereas our interest is in broadband delivered by wireless. It is not clear that the two modes of delivery will have similar economic externalities, especially in countries in which the population has access to both, where mobile broadband may be principally associated with use for consumption purposes – which may however generate non-economic externalities;
- Most of the work is done by agencies associated with the telecommunications sector, which may have a vested interested in strong results. This may lead to a selection bias, in consequence of which only positive results are disseminated.
- There may also issues about the thoroughness of pre-publication review. Only in a minority of cases (notably Czernich *et al.* 2011) have the results appeared in academic journals in which refereeing is the rule;[8]
- There are almost certainly missing variables in the estimated equations, ranging from investment in other activities (see below) to - closer to home - the presence or absence of adequate investment in digital literacy;
- It is worth noting that the communications sector is not alone in being identified as an engine of growth. Equivalent claims are made in respect of transport [16], infrastructure in general [17], as well as education and health [18]. More generally, the literature on endogenous growth theory (see for example Barro [18], Aghion & Howitt [19]) identifies a role for investment in public capital to augment long term growth rates. Angelopoulos et al. [20] find a positive effect on public investment on growth rates in OECD countries over an extended period. If broadband diffusion goes hand in hand with other developments, it may be hard to separate the effects. Moreover, if estimates of all the effects were applied at once, changes in GDP levels might be 'explained' several times over.

6. Conclusions

The direct estimates of the contribution of mobile communications to welfare and Gross Domestic Product cited in Tables 1 and 2 above are quite small: equivalent to 1 to 2% of GDP. At the same time we find some high estimates of total impact (including externalities) on GDP of the diffusion of mobile voice and of fixed broadband. Thus, if the estimates of Czernich et al. which suggest that a 50% diffusion of fixed broadband (a level now far surpassed in many countries) would lead to an increase in GDP of 4.5 to 7.5% apply also to mobile broadband, its spread could have a major impact on GDP. More research is needed to investigate this effect.

[8] This does not exclude the possibility of forms of refereeing in other outlets.

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Annex

Table 5 - Various estimates of the economic consequences of spectrum use

Year	Region	Form of economic value	Industry or action	% of GDP / Value
2012[9]	Australia	Direct and indirect economic contribution	Mobile communications	0.48%
2014[10]		Household consumption	Mobile broadband	$14.8bn
2011[11]	UK	Economic welfare (consumer and producer surplus)	Mobile communications	1.99%
			Wi-Fi	0.12%
			TV broadcasting	0.51%
			Radio broadcasting	0.2%
			Microwave links	0.22%
			Satellite links	0.24%
			Private mobile radio	0.08%
2008[12]	US	Productivity increase	Mobile communications	1.47%
2007[13]	Japan	Direct and indirect economic contributions	Mobile industries	1.68%
2010[14]	OECD area	Productivity increase	Mobile telecommunications	0.39%
2009[15]	Australia	Economic welfare (consumer and producer surplus)	Mobile broadband by UHF	0.089%
2011[16]	Latin	Consumer surplus	Mobile broadband at	0.068%

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	America		700 MHz	
2013[17]	European Union	Consumer surplus	Mobile services	2.04%
			Terrestrial broadcasting	0.37%
			Satellite communications	0.13%
			Private mobile radio	0.14%
			Civil aviation services	1.30%
2014 [18]	USA	Consumer surplus	LSA[19] from 100 MHz to 3.5GHz	0.08%
		Consumer surplus	LSA from 50 MHz to 2.3Ghz	0.04%

Source: Adapted, with additions, from New Approaches to Spectrum Management, OECD Digital Economy Papers No. 235, 2014, pp. 47-49. For further details, see the original, available at http://www.oecd-ilibrary.org/science-and-technology/new-approaches-to-spectrum-management_5jz44fnq066c-en

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[19] Licensed shared access.