THE ECONOMIC CONTRIBUTION OF RADIO SPECTRUM TO IRELAND

A report for ComReg

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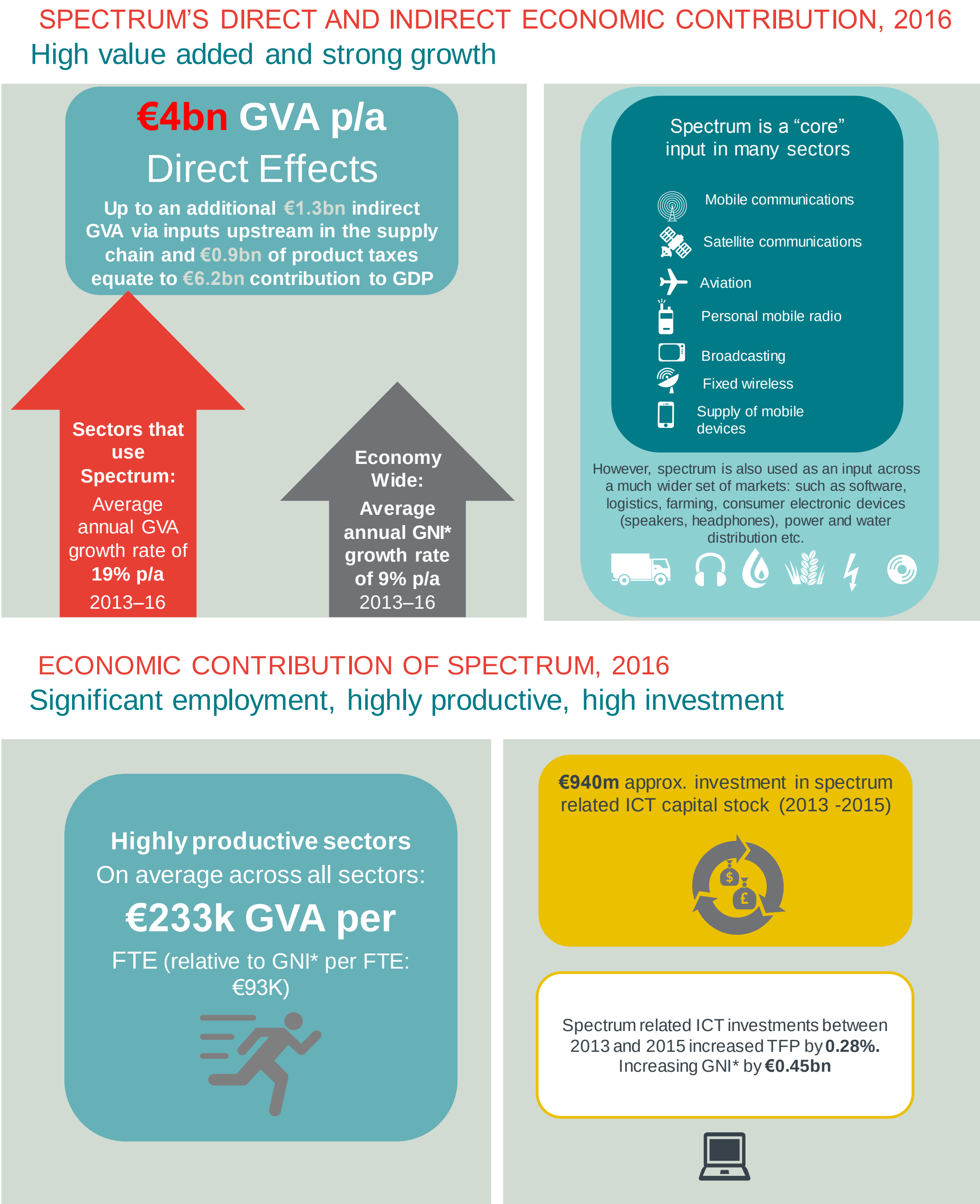
EXECUTIVE SUMMARY

Figure 1 Summary of contribution of the radio spectrum



Source: Frontier

1 INTRODUCTION

Spectrum is an input in many different sectors. Evolving wireless technologies mean that spectrum is now integral to many production processes and commercial practices. Spectrum is therefore an important contributor to economic outcomes in Ireland.

This report estimates the contribution that spectrum makes to the Irish economy.

Our analysis finds that the GVA (Gross Value Added)[1] associated with suppliers of products and services who use the radio spectrum as a core input was EUR 4 billion[2] in 2016. Furthermore these suppliers directly support employment of approximately 17,000 FTEs (Full Time Equivalents).[3] When the upstream impact of these activities is considered and the impact of net product taxes and subsidies, we estimate the total contribution of spectrum-dependent activities to be EUR 6 billion. This amounts to 3.5% of Irish GNI* in 2016 (Gross National Income)[4] [5].

Furthermore we estimate that spectrum-related investments in ICT (Information and Communications Technology) has led to additional annual Total Factor Productivity (TFP) growth of 0.28 percentage points in Ireland, implying additional GNI* of EUR 447 million in 2016.

The report is structured as follows:

- The remainder of this section provides an introduction to radio spectrum and introduces the approaches adopted by the report;
- Section 2 presents the estimates of economic activity in each sector where spectrum is used as a core input;
- Section 3 estimates the economic impact of radio spectrum on productivity of the Irish economy; and,
- Section 3 describes other sources of economic value that result from the use of the radio spectrum.

This report contains three annexes.

- ANNEX A describes the methodology for measuring value added of firms that directly use spectrum.
- ANNEX B describes the methodology for measuring the contribution that investments in spectrum technology make to productivity.

1 Gross value added is the difference between production value and intermediate consumption and represents the value added by the firm

2 This figure is in basic prices, meaning that it excludes net product taxes and subsidies

3 This estimate is likely to be conservative since it excludes data from some smaller providers and it excludes sectors which may rely on spectrum in a secondary way.

4 Gross national income is the sum of a nation's gross domestic product and the net income it receives from overseas. Gross National Income at market prices is equal to Gross Domestic Product minus primary income payable by resident institutional units to non-resident units plus primary income receivable by resident units from the rest of the world.

5 GNI* stands for modified GNI (Gross National Income) which is the preferred method for assessing national income in Ireland. Modified Gross National Income at current market prices is equal to Gross National Income at current market prices less the factor income of redomiciled companies, less depreciation on research and development related intellectual property imports and less depreciation on aircraft related to aircraft leasing

- ANNEX C summarises and responds to comments received on the methodology for assessing the contribution that spectrum makes to the Irish economy that ComReg consulted on as part of its Proposed Strategy for Managing the Radio Spectrum.

1.1 What is the radio spectrum?

The radio spectrum ("spectrum") is a specific range of frequencies of the electromagnetic spectrum that is used to communicate information and data. This natural resource is managed in Ireland by ComReg. Spectrum increasingly plays an essential part in many forms of economic activity. Indeed, spectrum is now a vital input in a variety of consumer, business and government activities. It can be used to transmit data just a few metres, such as in Bluetooth technologies, or to travel many kilometres to support long range communications.

The use of wireless technology may now be considered as a General Purpose Technology[6] (GPT), like electricity. This is because the ability to encode data and transmit and receive wirelessly has become pervasive to many different economic activities. Like other GPTs it has transformed how goods and services are produced, supplied and consumed.

However, technology markets that use spectrum evolve rapidly and advances in network capability and device technology create increasing demand for spectrum. For example, ComReg[7] previously described some of the technology markets relevant to management of spectrum in Ireland. These included:

- **Mobile services.** Mobile voice, text and data services are perhaps the most obvious user of spectrum for most people. Users increasingly see less distinction between their fixed and mobile networks and expect to be able to access their services, devices and content on both types of networks.
- **Broadcasting services.** A significant proportion of Irish households receive Digital Terrestrial Television that is transmitted in the ultra-high frequency (UHF) band. Similarly, Analogue radio (FM) retains high listenership while Digital radio has 54% population coverage.[8] Spectrum may, therefore, support public policy goals and social benefits associated with the provision of public service broadcasting.
- **Low power devices.** These can be used in a number of applications (either uni-directional or bi-directional) and can serve a multitude of purposes. These include, for example, remote car keys, baby alarms, wireless microphones and wireless local area networks (WLANs). Short Range Devices (SRDs) are deployed in both private and commercial scenarios. Private applications range from medical implants to cordless telephones. Commercial applications include

[6] General Purpose Technologies are characterized by pervasiveness (they are used as inputs by many downstream sectors), inherent potential for technical improvements, and innovational complementarities', meaning that the productivity of R&D in downstream sectors increases as a consequence of innovation in the GPT. See for example Timothy F. Bresnahan, M. Trajtenberg, General purpose technologies 'Engines of growth'?, Journal of Econometrics, Volume 65, Issue 1 1995, Pages 83-108,

[7] Electronic Communications Strategy Statement: 2017 – 2019 Reference: ComReg 17/31

[8] https://www.rte.ie/radio/page/138471-rte-radio-ways-to-listen/#digital-radio

public access wireless hotspots and radio frequency identification applications (RFIDs) used in logistics and inventory control.

- **The Internet of things (IoT)**. This describes a system of devices that have the ability to interact with their environment, and each other, without the physical constraints of geography. It is noteworthy that IoT is currently being provided across a range of technologies and platforms including 4G LTE-M, 4G NB-IoT, 2G GPRS, LoRA, and SigFox. Regulators need to ensure that there is sufficient spectrum available to support these services, and that providers and users have flexibility to support new and innovative IoT services which may arise in the future.
- **Fixed wireless point-to-point radio links.** These are used mainly by fixed and mobile operators, broadcasters, utilities and emergency services to provide transmission capacity and network backhaul, and to provide redundancy and back-up for other networks.
- **Satellite applications.** These include mobile and fixed telecommunications (satellite phones and intercontinental telecommunications links); broadcasting services, such as Direct to Home (DTH) multichannel television and Satellite Digital Radio (SDR); satellite broadband; Satellite News Gathering (SNG); meteorological services; space research; and Earth Exploration Service (EES) applications.

These sectors as set out by ComReg are used to inform the sectors from which this report estimates the economic impact from services that use spectrum[9].

1.2 Measuring the value of spectrum

ComReg has consulted on potential approaches[10] that could be used to estimate the contribution that spectrum makes to the Irish economy. As noted therein, measuring the economic contribution of spectrum is challenging. This is because:

- Spectrum is used in a number of goods and services which are themselves, in turn, inputs in a complex supply chain downstream, meaning the value of spectrum is felt in a wide set of markets.
- Spectrum is only one of a number of inputs in the goods and services that use it.
- The use of spectrum may have wider “spillover” economic impacts, such as productivity improvements or social benefits which should all be captured when estimating its overall contribution.
- In many cases spectrum is allocated for public use (and not for commercial purposes) such as for Disaster and Emergency Response or Defence, where the contribution to GVA can be more difficult to measure.

[9] We note that these sectors do not precisely reflect the sectors chosen in this study, though the activities map to the sectors chosen. For example low power devices and IoT devices are typically found in a wide variety of consumer devices across a number of sectors (see section 2.1.8).

[10] ComReg Document 18/74, Proposed Strategy for managing the radio spectrum 2019 – 2021, published 3rd August 2018.

In light of these issues the consultation suggested two separate but complementary approaches would be used to assess the contribution of spectrum to the Irish economy. These approaches considered different aspects of the economic value created by spectrum. The two approaches chosen to measure the value of spectrum are described in the annex and summarised below.

Approach 1: The economic value added in sectors where spectrum is a core input

The first approach measures the economic activity in those sectors where spectrum is used as a "core" input. Specifically, using data from both the Companies Registration Office (CRO) and Central Statistics Office (CSO) it measures the GVA produced in the Irish economy of suppliers of goods and services that use the radio spectrum as a core input.

The GVA of a given sector (or sectors) can be compared to national income metrics such as Gross Domestic Product[11] or GNI* to estimate the proportionate contribution of those sectors where spectrum is a core input. Furthermore it is also possible to estimate the employment in the sectors where spectrum is a core input.

In addition we note that when producing output in a given sector there is incremental "indirect" value added created in upstream sectors that supply inputs to that sector. Therefore we estimate the incremental "indirect" value added[12] based on input-output tables provided by the CSO.[13]

Approach 2: The economic impact of radio spectrum on productivity of the Irish economy

The second approach measures the impact that investments in spectrum related technologies make to the productive capacity of the Irish economy.

Investment in spectrum related capital can improve firm efficiency and thereby increase the economy wide productivity. It enables more efficient production processes, or organisational structures; or enables the supply of new and innovative services and features. These impacts can lead to economy wide efficiency gains which increase the productivity capacity of the economy.

[11] Gross Domestic Product (at market prices) is equal to Gross Value Added at basic prices plus taxes on products less subsidies on products (such as VAT or excise duties). It represents total expenditure on the output of final goods and services produced in the country ("final" means not for further processing within the country) and valued at the prices at which the expenditure is incurred.

[12] For the reasons set out in the annex, the estimates of indirect value added are necessarily less precise than the estimates of the direct effects.

[13] The Supply and Use and Input-Output Tables provide a detailed picture of the transactions of goods and services by industries and consumers in the Irish economy in a single year. They highlight the inter-industry flows that lie behind the National Accounts main aggregates such as gross output, operating surplus and external trade movements, etc.

2 MEASURING THE ECONOMIC CONTRIBUTION OF SECTORS WHICH RELY ON SPECTRUM

We have estimated economic activity in Ireland for those sectors that rely on spectrum. These are sectors where the use of spectrum is "core" to the services being provided. It is likely that in the absence of management of the spectrum resource that economic activity in these sectors would be significantly diminished.[14]

- In section 2.1 the total economic value added (and employment) in the sectors where spectrum is a core input is estimated[15];
- Section 2.2 estimates the additional incremental economic value added as a result of supplying inputs to sectors that rely on spectrum; and,
- Section 2.3 sets out the employment in sectors that rely on spectrum.

2.1 Measuring the direct impact of spectrum to the Irish economy

The direct impact of spectrum to the Irish economy can be considered as the gross economic value added which is created in the sectors that rely on spectrum as a core input (which ComReg consulted on[16]). These are:

- Operation of mobile services
- Manufacture of mobile devices
- Sale and distribution of mobile devices
- Wireless broadcasting
- Aviation
- Fixed wireless
- Professional Mobile Radio (PMR)

For each sector we provide an assessment of the suppliers in each sector and identify the GVA produced in Ireland for the years 2013 - 2016[17].

GVA describes the contribution to economic output in a given sector. It is defined as economic output minus intermediate consumption. It can be estimated by summing the gross operating profit earned by suppliers in the sector of interest with the compensation of employees and self-employed earnings. We can, therefore, identify suppliers in the sectors where spectrum is a core input, and

[14] There is a degree of judgement in identifying sectors where the use of spectrum is "core" the production or distribution of the good or service.

[15] In section 4.1 we describe other sectors where spectrum is used but is not a "core" input

[16] ComReg Document 18/74, Proposed Strategy for managing the radio spectrum 2019 – 2021, published 3rd August 2018.

[17] We note that 2017 data was not available at the time of preparing this report.

examine their Annual Financial Accounts (obtained from the Companies Registration Office) to estimate their direct contribution.

2.1.1 Operation of mobile services

The mobile sector in Ireland includes the three Mobile Network Operators (MNOs). These are eir, Three, and Vodafone. These operators provide mobile network voice and data services to consumers and businesses. At the end of June 2018 there were 6,120,535 mobile subscriptions in Ireland. This includes 930,806 Machine to Machine ('M2M') subscriptions[18].

The sector also includes the value added output from Mobile Virtual Network Operators (MVNOs) such as Tesco Mobile, Lycamobile and Virgin Mobile. These operators purchase wholesale services from MNOs and use these to supply mobile services to consumers.

The mobile services sector clearly relies on spectrum for its operations, as it provides mobile services (such as calls and data) which are entirely dependent on the use of spectrum.

In calculating this sector`s GVA and employment, we consider the major mobile network operators (e.g. Vodafone, eir, Three), who represent a majority of sector turnover, as well as MVNOs[19]. It should be noted that some of these providers also provide fixed-line services. Fixed services are clearly not dependent on spectrum to provide such services so we have estimated each companies' spectrum related GVA[20].

Direct GVA and employment estimates are presented in Figure 2.

Figure 2 Direct GVA and employment: operation of mobile services

	2013	2014	2015	2016
GVA at basic prices (€`000s)	€477,000	€386,000	€545,000	€581,000
Employment	2,500	2,900	2,500	2,500

Source: CRO, Frontier calculations

Notes: There are also macro estimates available from the CSO for wireless telecommunications services (NACE2 code: 612). They estimate that the GVA of the sector was approximately €630 million in 2016, which is comparable to our micro-level estimates. Notes: Figures are rounded.

2.1.2 Manufacture of mobile devices

The manufacturing of mobile equipment can include the manufacture of mobile devices and mobile network equipment. There are a number of suppliers that base Research and Design services in Ireland. For example, Ericsson employs 1,200 staff in its Athlone and Dublin campuses,[21] Huawei has operations in Ireland

[18] See: https://www.comreg.ie/publication-download/quarterly-key-data-report-q2-2018

[19] We were not able to capture all MVNOs in the analysis as the accounts they submit to CRO are not detailed enough to allow the calculation of GVA.

[20] Using the methodology as set out in the Methodology consultation ComReg 18/74a. GVA at basic prices = Gross operating surplus + compensation of employees.

[21] See: https://www.siliconrepublic.com/companies/ericsson-job-cuts-ireland

supplying telecommunications infrastructure[22] and Adaptive Mobile, based in Ireland, provides mobile network security services to worldwide customers.

It is not clear that the GVA associated with these companies solely relates to mobile services or equipment. This is because all companies produce a range of telecommunications and other equipment. Therefore, using some assumptions, we adjust our GVA estimates so that they only reflect estimated spectrum related activities[23].

Direct GVA and employment estimates are presented in Figure 3.

Figure 3 Direct GVA and employment: manufacture of mobile devices

	2013	2014	2015	2016
GVA at basic prices (€`000s)	€127,000	€148,000	€159,000	€160,000
Employment	1,400	1,600	1,700	1,700

Source: CRO, Frontier calculations

Note: There was no data available for Adaptive Mobile for 2016. We have assumed that the company`s GVA in 2016 was the same as in 2015. Notes: Figures are rounded.

2.1.3 Sale of mobile devices

Within this category we also consider a number of independent wholesalers and retailers of mobile services.[24] Note that to a small extent, these companies also sell devices that are not directly relevant for this analysis. For example, some suppliers sell laptops which use spectrum (for example to support wireless connectivity via Wi-Fi or Bluetooth) but where spectrum is not “core” to the supply of these goods. Furthermore, there are also likely to be a number of small retailers who we have not included since they were too small.

Direct GVA and employment estimates are presented in Figure 4.

Figure 4 Direct GVA and employment: sale of mobile devices

	2013	2014	2015	2016
GVA at basic prices (€`000s)	€20,000	€18,000	€11,000	€20,000
Employment	700	700	700	700

Source: CRO, Frontier calculations Notes: Figures are rounded.

2.1.4 Wireless broadcasting

TV broadcasting relies on spectrum in a number of ways. This principally relates to the transmission of TV broadcasting via terrestrial TV networks; satellite TV networks or streaming via mobile networks. Our analysis therefore includes the major TV broadcasters including RTÉ, TV3, TG4. It also includes the satellite TV provider Sky.

[22] See: http://www.huawei.com/en/press-events/news/2016/10/new-Dublin-office

[23] Specifically we pro rate GVA by the proportion of company revenues that are related to spectrum activities.

[24] Mobile operators are also involved in the sale and distribution of devices. However, the GVA associated with this activity will have been included in the segment discussed in Section 2.1.1 above.

While historically, terrestrial broadcasting was the only way for users to receive television services, broadcaster's channels are now also received via wired cable networks (from Virgin Media) or the internet. We have, therefore, adjusted the GVA of the companies included in the analysis to only reflect GVA that is associated with spectrum-dependent methods of distribution[25].

Radio broadcasting in Ireland includes a range of national and local voice and music based services. Traditionally, radio stations were only available via terrestrial broadcasting which relied on spectrum. Now services are also supplied using wired communications (e.g. via the internet). In addition to RTÉ, who provides radio services, we also include providers such as Communicorp and Landmark Media Investments[26] who both own a number of radio broadcasters in Ireland. However, our analysis of the radio segment excludes the many small radio broadcasters which do not report financial data to the CRO. Also included in this sector is Abhann Productions (however we note that not all Abhann's spectrum related revenues may relate directly to wireless broadcasting).

Direct GVA and employment estimates are presented in Figure 5.

Figure 5 Direct GVA and employment: wireless broadcasting

	2013	2014	2015	2016
GVA at basic prices (€`000s)	€342,000	€350,000	€368,000	€328,000
Employment	3,600	3,700	3,900	3,800

Source: CRO, Frontier calculations

Note: Some broadcasters (e.g. TG4) receive significant state subsidies; these are included in the calculation and treated as revenues.
There was no data available for TV3 for 2015-16. We have assumed that the company`s GVA in both years was the same as in 2014. Figures are rounded.

2.1.5 Aviation

Aviation relies on spectrum for specialist communication, safety, data broadband links, and navigation. Ireland is home to a number of airlines including Ryanair which is one of the largest airlines in Europe, as well as Aer Lingus and Cityjet.

In this sector we have also included the GVA associated with suppliers of airport services. We note that sector level data for Aviation Services is available from the CSO. Given the difficulties in obtaining reliable estimates[27] for this sector, we consider the use of CSO data for Aviation to be appropriate.

Direct GVA and employment estimates are presented in Figure 6.

[25] Specifically we pro rate GVA by the proportion of company revenues that are related to spectrum activities.

[26] We note that all of Landmark Media Investments` interests have been acquired by the Irish Times as of July 2018 (see here: https://www.irishexaminer.com/breakingnews/business/irish-times-complete-purchase-of-landmark-media-pledge-to-protect-identity-and-independence-of-titles-854228.html)

[27] The aviation services sector is characterised by a number of multi-territory suppliers who supply services seamlessly across a number of countries. It can therefore be difficult to identify the share of value added that was produced in Ireland from reported financial data. Therefore we rely on CSO data on national accounts to estimate GVA of the sector.

Figure 6 Direct GVA and employment: aviation

	2013	2014	2015	2016
GVA at basic prices (€`000s)	€1,317,000	€1,874,000	€2,457,000	€2,822,000*
Employment	NA	NA	8,100	8,200

Source: CSO, Frontier calculations

*Note: * The CSO did not publish GVA estimates for the sector for 2016 (at the time of drafting). The figure in the table is interpolated using the 2015 figure and growth between 2015 and 2016 of the estimated share of GVA of aviation services suppliers, where each supplier's GVA is scaled by the share of revenues they report to be from Ireland. The CSO report GVA estimates at factor cost; these have been transformed into estimates at basic prices using information from the CSO`s multiplier tables. Figures are rounded.*

2.1.6 Fixed wireless

Fixed wireless technologies are used to connect fixed locations (e.g. buildings) via a wireless link in rural and urban locations. Furthermore, they are often used in the provision of internet and other services to areas of low population density, where the construction of wired telecommunications infrastructure would not be economical. If spectrum was unavailable, these wireless services could not be provided and fixed services could only serve as a substitute to a limited extent.

Our analysis focuses on fixed wireless internet providers and includes the value added from the provision of Fixed Wireless services. There are also many regional providers that are small and do not report the financial information required for the GVA calculation in their financial accounts. Furthermore broadcasters, mobile operators and utility providers may self-supply fixed wireless to support their services. This self-supply will not be included within the estimates below. As such, we may be underestimating the GVA contribution of the fixed wireless sector.

Direct GVA and employment estimates are presented in Figure 7.

Figure 7 Direct GVA and employment: fixed wireless

	2013	2014	2015	2016
GVA at basic prices (€`000s)	€8,000	€7,000	€18,000	€7,000
Employment	200	200	200	200

Source: CRO, Frontier calculations

Note: Imagine had negative GVA in 2016, which has a significant effect on the results. There was no data available for Digiweb for 2016. We have assumed that the company`s GVA in 2016 was the same as in 2015. Figures are rounded.

2.1.7 Professional Mobile Radio (PMR)

Professional mobile radio services are specialised mobile communication services that are often used by police forces and fire brigades, as well as certain commercial sectors.

Direct GVA and employment estimates are presented in Figure 8.

Figure 8 Direct GVA and employment: professional mobile radio

	2013	2014	2015	2016
GVA at basic prices (€`000s)	€31,000	€30,000	€32,000	€33,000
Employment	100	100	100	100

Source: CRO, Frontier calculations Notes: Figures are rounded.

2.1.8 Other sectors

In addition to the sectors considered above there are a number of other sectors where the use of spectrum is important but which are not considered as part of this analysis, due to a lack of available data. We note that our estimates of the total contribution of spectrum to the Irish economy are likely to be conservative.

Satellite communications services

Satellite services provide connectivity via networks which use a combination of ground based stations which downlink / uplink to a network of satellites which orbit the earth. Satellite data services provide specialist services to businesses, broadband in very rural areas, data to aircraft and maritime, support broadcasting and in some cases, international telecommunications services.

We were unable to estimate the GVA associated with this sector directly either from company or CSO national accounts data.

Licence exempt spectrum

ComReg defines certain categories of spectrum as being licence exempt. This means that the spectrum can be used without a licence by multiple users, provided that it is used in accordance with conditions set out by ComReg[28]. In some cases the use of licence exempt spectrum is for commercial purposes (for example in some cases licence exempt spectrum supports Fixed Wireless, or Wide Area Networks).

However, there are a wide range of other radio systems used by consumers and businesses which are exempt from licencing. These include Wi-Fi, Radio-frequency identification (RFID). We have defined licence exempt spectrum (which is not already included in the sub-sectors defined above) as not a "core" element[29]. This is because the use of spectrum forms a minor part of a more complex application (e.g. to support access and security in car keys used in the manufacturing of motor cars) or it is relatively easy to substitute with fixed technologies.

PMSE

Programme Making and Special Events (PMSE) refers to equipment and services used to support broadcasting, news gathering, theatrical productions etc. Much of

[28] See: https://www.comreg.ie/industry/radio-spectrum/licence-exemptions/

[29] A number of Fixed Wireless services are provided over licence exempt spectrum (e.g. 5.8 GHz).The radio spectrum for such uses would be considered core and was assessed separately above.

this equipment is wireless, and is often used for the creation of content for radio and television broadcasting. As such, a significant portion of GVA associated with the manufacture and sale of these devices and services is dependent on spectrum.

PMSE equipment is mostly manufactured and sold by large global companies, which do not publish separate statistics about this specific segment.

Closely related non-core sectors such as content creation, advertising and supporting services

The growth in the use of mobile data telecommunications services has been driven by a complementary growth in demand for digital services such as mobile content, services and advertising. To the extent that these services rely on spectrum in order to be able consume and distribute content (whether on mobile networks or using fixed Wi-Fi networks) then they are likely to rely to some degree on spectrum. In practice there are a wide variety of sectors that will be enabled by spectrum related activities.

The mobile content value chain includes a number of suppliers of different services. The markets for mobile content creation, advertising and supporting services include a range of providers in a set of inter-linked complementary markets described in Figure 9 below.

Many mobile services and applications rely on advertising revenues. Arguably a significant proportion of mobile advertising is reliant on spectrum in that if spectrum were not available the advertising would not be displaced to other mediums. A recent report[30] prepared by IAB Ireland estimates that mobile advertising expenditure in Ireland amounted to €231 million in 2016. This is likely to be dispersed across the mobile value chain in the different services as set out in Figure 9.

[30] The report is available at: https://iabireland.ie/research-case-studies/adspend/

Figure 9 Mobile, content advertising and supporting services

Value chain	Services	Description
Upstream	Content rights	Rights to distribute TV, sports movies content etc. via mobile services
Online services	Application design and service creation and distribution	Design and hosting of software which is used on mobile devices
	Mobile payment platforms	Companies providing transaction systems that process end-user mobile online payments
	Mobile advertising services (mobile agencies, online ad networks, ad servers)	Ad agencies place advertising and may take part in the editorial process for creating advertising.
	Mobile internet analytics	Provides analytic services on the volume of consumption.
	Mobile Content Delivery Networks (CDN)	Supply of managed bandwidth to ensure that content can be delivered to end users.

Source: Frontier

2.1.9 Summary of direct economic value added in sectors where spectrum is a core input

Based on the analysis that we have undertaken, we estimate that the direct economic value added in those sectors where spectrum is a core input was €3.8bn in 2016.

This relates to the economic activity of companies whose operations are dependent on the use of spectrum (either in Ireland or elsewhere).

Figure 10 GVA (€000s, current prices)

€`000s	2013	2014	2015	2016
Broadcasting	€342,000	€350,000	€368,000	€328,000
Mobile	€477,000	€386,000	€545,000	€581,000
Aviation	€1,317,000	€1,874,000	€2,457,000	€2,822,000
Mobile Manufacture	€127,000	€148,000	€159,000	€160,000
FWALA	€8,000	€7,000	€18,000	€7,000
PMR	€31,000	€30,000	€32,000	€33,000
Mobile Retail	€20,000	€18,000	€11,000	€20,000
Direct GVA at basic prices	**€2,323,000**	**€2,814,000**	**€3,589,000**	**€3,952,000**

Source: Frontier Notes: Figures are rounded.

2.2 Indirect economic value added

2.2.1 Indirect effects

In a modern economy, supply chains are complex, meaning that many industries may be involved in the provision of a final good or service. However, the direct GVA assessed in section 2 does not capture the GVA of economic activities upstream used to supply services where spectrum is a core input.

The GVA of such upstream activities (indirect GVA) can be estimated using a multiplier approach. The relevant multipliers describe the relationship between the output of each sector and *total GVA* (direct plus indirect) arising in the entire economy as a result of output in the specific sector. Frontier has estimated relevant multipliers using data and analysis published by the CSO.

In doing so we adjust the multiplier estimates to avoid a potential double count where indirect activity in a sector (identified via the multiplier analysis) is already included in the direct economic activity described in section 2.[31]

Figure 11 Total GVA associated with core spectrum sectors

	2013	2014	2015	2016
Direct GVA at basic prices (€`000s)	€2,323,000	€2,814,000	€3,589,000	€3,952,000
Indirect GVA at basic prices (€`000s)	€675,000	€892,000	€1,170,000	€1,329,000
Direct + Indirect impact (€`000s)	€2,998,000	€3,707,000	€4,759,000	€5,281,000

Source: Frontier Notes: Figures are rounded.

There are a number of caveats related to the approach described above which need to be considered when interpreting the results set out in Figure 11.

- The multipliers we use are estimated by the CSO.
- These multipliers are only available at the 2-digit NACE code level, meaning that they do not map perfectly to our definitions of sectors where spectrum is a core input.[32]
- These multipliers are only available for 2015[33], and the GVA-to-output ratios may vary from year to year, depending on the performance of the given sector.

2.2.2 Comparison of GVA to national output

In order that our measure of economic activity can be compared with GDP or GNI it is necessary to include the relevant product taxes (net of subsidies)[34]. At an

[31] To estimate multiplier impacts we recalculate the coefficients on sector production which are produced by CSO. In doing so we omit upstream multiplier impacts in those sectors where we already directly identify downstream activity (i.e. those sectors set out in section 2.1).

[32] For example, while our GVA estimates for mobile service producers should be based on multipliers for the wireless telecommunication sector (NACE code 612), only the multiplier for the telecommunications sector as a whole is available (NACE code 61). We consider this to be a suitable proxy for wireless telecommunications.

[33] At the time of this analysis.

[34] Since GDP can be calculated as GVA plus product taxes net of subsidies.

economy wide level (i.e. not at the level of each sector) we therefore also estimate the product taxes which result from a given level of output. Product taxes relate to taxes that vary with volume (such as Value Added Tax, excise duties etc).

The resulting total economic output which results from economic activities which rely on the use of spectrum as a core input in Ireland is set out in Figure 12. As set out here, we estimate that the economic activity measured by GDP that results from supply of goods and services in Ireland where spectrum is a core input amounts to €6.2bn in 2016. This amounted to 3.5% of GNI*.

Figure 12 Total GVA and employment associated with core spectrum sectors

	2013	2014	2015	2016
Direct GVA at basic prices (€`000s)	€ 2,323,000	€ 2,814,000	€ 3,589,000	€ 3,952,000
Indirect GVA at basic prices (€`000s)	€ 675,000	€ 892,000	€ 1,170,000	€ 1,329,000
Product taxes less subsidies (€`000s)	€443,000	€623,000	€817,000	€937,000
Total contribution to GDP (€`000s)	€3,441,000	€4,329,000	€5,576,000	€6,218,000
Contribution to GNI*	2.5%	2.9%	3.5%	3.5%

Source: Frontier

Notes: The analysis does not compare the contribution of spectrum and related sectors to GDP or GNI. This is because the specific characteristics of the Irish economy mean that GDP and GNI can be volatile in a way that does not reflect the productive capacity of the Irish economy. Therefore, the CSO publishes "GNI" in order to remove three specific contributors to the volatility in Irish national accounts and to better reflect the living standards of Irish residents (the effects of redomiciled headquarter of multinational public limited companies; aircraft leasing sector, on-shoring of intellectual property assets[35]). Figures are rounded.*

2.3 Total employment

Figure 13, below, shows the total employment associated with the direct economic activity in sectors where spectrum is used as a core input. In total we estimate that over 17,000 full time equivalent (FTE) workers are employed in these sectors.

[35] See: https://www.finance.gov.ie/wp-content/uploads/2018/05/180504-GDP-and-Modified-GNI-Explanatory-Note-May-2018.pdf

Figure 13 Total employment

Employment (FTEs)	2013	2014	2015	2016
Broadcasting	3,600	3,700	3,900	3,800
Mobile	2,500	2,900	2,500	2,500
Aviation	NA	NA	8,100	8,200
Mobile Manufacture	1,400	1,600	1,700	1,700
FWALA	200	200	200	200
PMR	100	100	100	100
Mobile retail	700	700	700	700
Total Employment	**NA**	**NA**	17,000	17,000

Source: Frontier, CSO Notes: CSO did not publish employment data for the Aviation sector in 2013 or 2014. Figures are rounded.

Our analysis suggests spectrum related economic activities tend to be associated with higher labour productivity which is a key driver of economic growth. One measure of labour productivity is GVA per worker. This measures the economic output produced for each worker. We estimate that total GVA (at basic prices[36]) per full time employee in the sectors surveyed is around €233,000. This compares to a GNI* per full time employee of €93,000.[37]

[36] GVA at basic prices excludes net product taxes and subsidies.

[37] Note that the economy-wide GNI* per full time employee is not a perfect comparator to GVA per full time employee estimated in our model. In theory, the figure that should be used is economy-wide GVA at basic prices per full time employee (€128k). However, we have decided to use the GNI-based figure as in practice, Irish GVA and GDP figures can be volatile.

3 THE ECONOMIC IMPACT OF RADIO SPECTRUM ON PRODUCTIVITY OF THE IRISH ECONOMY

3.1 Introduction

Radio spectrum is an important input in economic activity. Section 2 sets out the *direct* gross value added in those sectors where spectrum is an essential, or core, input, including the operation of mobile services, radio broadcasting, and aviation among others. Economic activity in these industries could not take place without spectrum. However, as spectrum related technologies permeate throughout the economy (in the sectors set out in section 2 as well as all other sectors that use spectrum) these investments lead to improvements in productivity in these sectors.

In this section we have estimated the impact that investments in spectrum related technologies have on economy wide productivity. In this, we define productivity as 'Total Factor Productivity' (TFP).[38] Productivity, measured as TFP, increases when an economy becomes more efficient at using a given amount of capital and labour. There is evidence that ICT capital has an impact on TFP over and above that of other forms of capital (such as buildings or plant machinery). Therefore, if spectrum enables investment in ICT that would not have happened otherwise, we would expect this to determine greater TFP growth. This would still be the case even if the additional spectrum-related ICT investment came at the expense of investment in other forms of capital.

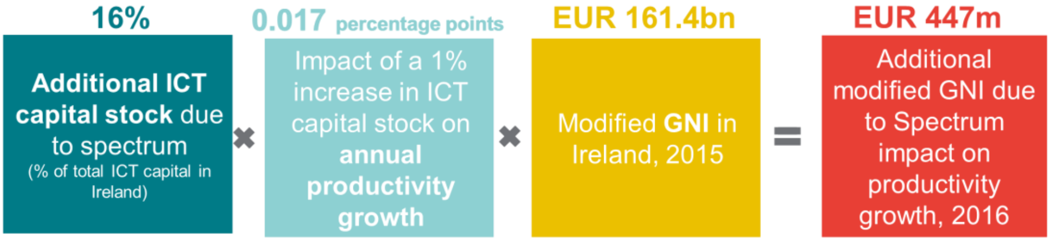
3.2 Results: the likely impact of spectrum on productivity growth in Ireland

We estimate that spectrum-related ICT investment between 2013 and 2015 has led to TFP being 0.28 percentage points higher than it otherwise would have, implying additional GNI* of EUR 447 million in 2016.

This is a conservative estimate, given the assumptions described in the earlier sections of this note. Specifically, this only measures the effect that spectrum-related ICT capital has by making the Irish economy more efficient in combining workers and machines to produce economic output. Therefore, our estimates only include the returns to ICT equipment that are in excess of typical returns to capital assets such as buildings, plant machinery, and others.

[38] *Total Factor Productivity (TFP) is defined as "the portion of output not explained by the amount of inputs used in production" (Comin, 2006).*

Figure 14 Calculation of central estimate



Source: *Frontier calculations based on CSO, Eurostat, International Telecommunications Union data and existing economic literature*

We obtain the impact of spectrum related ICT investment by combining estimates of the proportion of the ICT capital stock due to investment in to spectrum activities (step 1); and estimates of the relationship between change in the ICT capital stock and TFP (step 2).

From Step 1, we know that investments in spectrum related ICT capital between 2013 and 2015 means the ICT capital stock is 16% higher 2015 than it otherwise would be.

Step 2 estimates that a 1% increase in the ICT capital stock is linked with a 0.017 percentage point increase in annual TFP growth. Therefore, we multiply 0.017 by 16.3 (0.163/0.01) to know the likely impact of spectrum on TFP (0.28 percentage points higher) compared to a counterfactual where the investment did not take place. This 0.28 percentage points effect is a change in the annual growth of GNI* between 2015 and 2016. Therefore we multiply 0.28/100 by the level of GNI* in 2015 to estimate the additional GNI* in 2016 that is due to changes in spectrum related ICT capital.

3.2.1 Interpreting this analysis

In interpreting the analysis there are a number of factors that should be considered. This analysis focusses on the impact of the three years of spectrum-related investment on the productivity of the Irish economy which is consistent with the assessment period of this report. It does not try to assess the impact of the entire spectrum-related capital stock (relative to a counterfactual of no spectrum related capital stock). This is because the econometric techniques that have been used to assess the impact of ICT (the 0.017 coefficient above) are only able to estimate the impact of *relatively small ("marginal") changes* in ICT stocks on TFP. Therefore, if we applied the 0.017 coefficient to a larger change in ICT capital stock (due for example to five years of spectrum-related investment), we may under- or over-estimate the impact of that change.

The above analysis provides an estimate of the impact of spectrum through enhanced productivity on the total Irish GNI*, including core spectrum sectors. Therefore, it is not advisable to add the EUR 447 million to the GVA estimates of the impact of spectrum presented in Sections 2 of this report. Doing this would involve some double-counting and overestimate the total impact of GVA on the Irish economy.

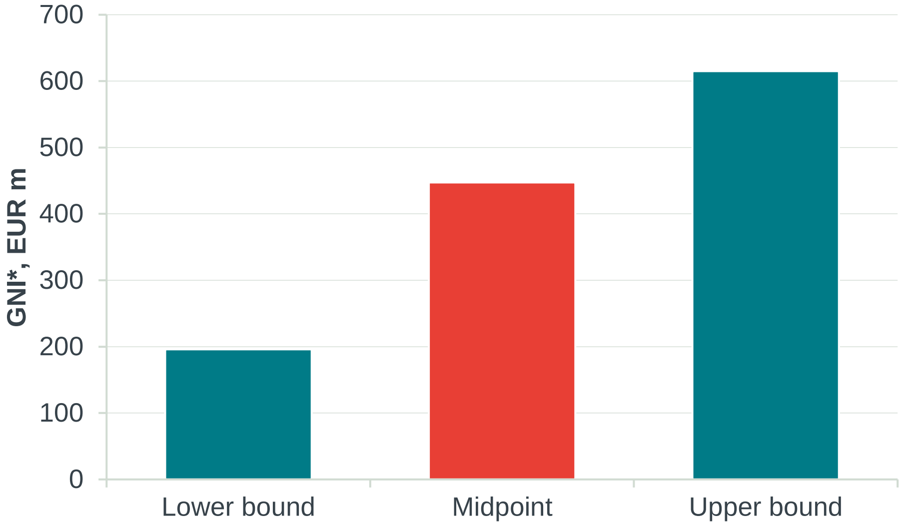
To avoid double-counting when estimating the total impact of spectrum on Irish GNI, one would have to add to the direct and indirect impact and only the productivity impact that has been generated outside of core spectrum sectors. However, available data do not allow us to do this, as there is limited information on the ICT capital and TFP growth specific to core spectrum sectors in Ireland.

We can at least get an idea of how much of the productivity effect is produced outside of core spectrum sectors using data on ICT capital from other countries and making assumptions on how the impact of ICT on productivity varies across sectors. In the UK, 20% of total ICT capital stock is installed in core spectrum sectors (Telecommunications, Air transport, and Motion picture production and Broadcasting). Therefore, if we assume that this proportion is similar in Ireland, and that the impact of ICT capital on TFP is constant across sectors, that would imply that around 80% of the impact of spectrum on GNI* estimated here (EUR 447m) would be additional to the direct impact of spectrum.

3.2.2 Sensitivity estimates

Our estimate of the impact of changes in spectrum related ICT stock on GNI* relies on a central point estimate from a range of existing international estimates of the impact of ICT capital stock on productivity growth. Figure 15 below shows how choosing a lower or higher estimate from the existing evidence base would affect our results, compared to the base case.[39]

Figure 15 Robustness of results to modelling assumptions, 2016



Source: Frontier Economics calculations

The base case is the central estimate in a range varying from EUR 196m to EUR 615m. Figure 22 in ANNEX B shows the calculations underlying the alternative estimates.

[39] The lower bound corresponds to the first quartile of the list of estimates we have collected (the point such that 25% of all estimates are below) and the upper bound corresponds to the third quartile of the list (the point such that 75% of all estimates are below).

3.3 Conclusion

Spectrum is used widely across all sectors. While it is an "essential input" in sectors set out in section 2, it is used across many different sectors. Investment in ICT capital used in the Irish economy as a result of spectrum is likely to contribute to productivity growth across a range of sectors and therefore lead to additional modified Gross National Income (GNI*) across the economy. In this section, we estimate the scale of this contribution. Due to data limitations, we focus specifically on the impact of investment in mobile network infrastructure.[40]

In each year, investment in spectrum-related equipment contributes to the overall stock of ICT capital in the economy. We estimate investments in spectrum equipment made over three years (2013-15) mean that (the real[41] value of) the ICT capital stock at the end of the period (2015) is 16% higher than it would have been otherwise. This is equal to EUR 940 million (in constant 2015 prices).[42]

We estimate that spectrum-enabled investment in ICT equipment between 2013 and 2015 generated additional GNI* in Ireland of EUR 447 million in 2016 (0.28% of total GNI* in 2016).

Due to limitations in the data and evidence available, this estimate relies on a number of assumptions. Varying these assumptions within plausible ranges, our estimate of the total impact of spectrum-enabled ICT equipment on Ireland's GNI* in 2016 varies between EUR 196 million and EUR 615 million.

[40] However, spectrum enables broader ICT investment: investment in telecommunications equipment that could not function without spectrum (e.g. smartphones) but also equipment that could function but the value of which might be lower without spectrum (for example, spending on laptop computers may be lower if they could not connect to the Internet via wireless technology).

[41] All figures used in this calculation are at constant 2010 prices, and therefore are not influenced by inflation.

[42] In EUR 790 million (in constant 2010 prices) equates to EUR 940 million in 2015 prices, out of a total value of the Irish ICT capital stock of EUR 5.76 billion. Source for total ICT capital stock value: Eurostat.

4 OTHER SOURCES OF VALUE

The value of spectrum is felt not just in those sectors where it is a core input (mobile or other forms of communications, aviation and broadcasting). We set out below some of the other benefits from the use of spectrum.

- Section 4.1 describes the benefits from the use of spectrum in those sectors where spectrum is not a “core” input.
- Section 4.2 describes the economic welfare that consumers derive from the use of goods and services that rely on spectrum.
- Section 4.3 describes how spectrum can enable a number of social goals, which can be difficult to quantify.

4.1 Other sectors where spectrum is not a “core” input

The analysis presented in section 2.1 identifies the GVA created by suppliers of products and services that rely on spectrum as a “core input”. However, there are a multitude of other sectors across the economy that use spectrum in some way.

Furthermore, the goods and services described in section 2.1 are themselves inputs in the supply of goods and services. Just as spectrum enabled applications are important consumer goods, it is difficult to think about other commercial activities which do not rely on wireless communications in some way. For example, spectrum for wireless communications is often used as a way to augment the quality of services and products.

4.1.1 Consumer applications

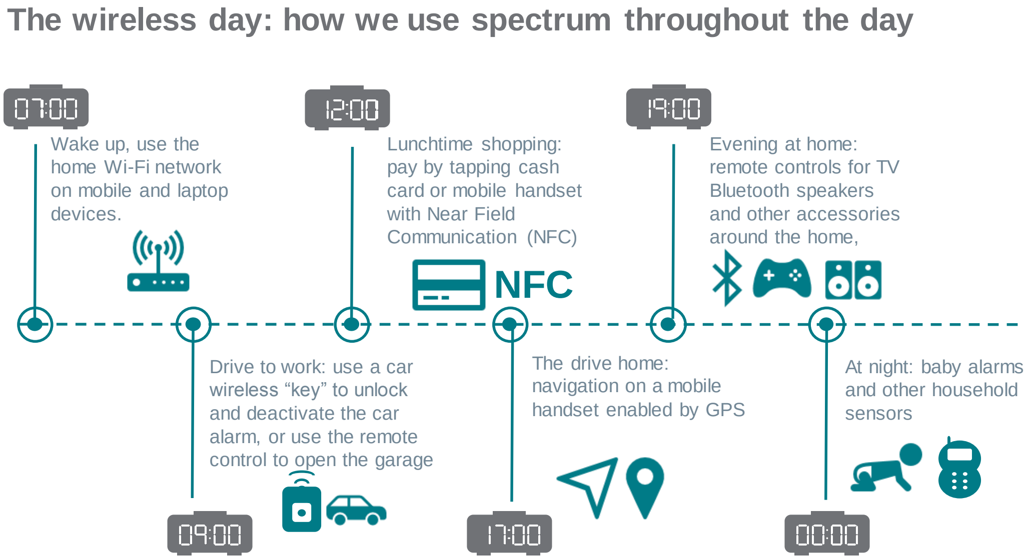
We now take for granted spectrum enabled wireless communications in our home. Households typically now have a wireless “Local Area Network” enabled by their home router which connects all manner of devices. In addition to laptops, PCs, tablets and phones, households will also connect many other “smart” devices such as PC accessories (scanners or printers), home thermostats, gaming devices, TVs, security devices, baby monitors and so on. All these devices communicate over a single in home network, and can access any other device connected to the internet using the home internet connection.

The growing adoption of internet of things will mean that the number of devices connected to the internet via wireless home networks will grow, for example to encompass, smart lighting, locks, or monitoring devices.

In addition there are a number of other “short range” devices that might be used in home or for other consumer uses. These range from the remote controls for in-home devices (TVs, garage door openers); identification transmitters (for example those used in contactless payments, or pet identifiers); cordless phones; vehicle alarms; or motion detectors and positioning transmitters (for example for navigation).

The use of spectrum across a typical day in Figure 16 illustrates how spectrum is now integral to all our consumer activities.

Figure 16 The wireless day



Source: Frontier

4.1.2 Business applications

Unsurprisingly, businesses are quick to adopt new wireless applications that can improve productivity. They will invest in inputs which reduce costs, increase efficiency or provide innovative features which their consumers' value.

The benefits of using wireless technology on the wider economy productivity will to an extent be identified in the estimates of productivity gain (set in out section 3).

Utilities

Utilities

Utilities use spectrum to provide monitoring to support reliability and resilience of service.

Utilities (such as gas, electricity and water networks) use wireless communications for a number of reasons. Typically utility companies' networks extend widely in geographic scope. The infrastructure to service the networks will include power stations, pumping stations, reservoirs, electricity sub-stations. In order to be able to able to properly monitor and measure activity, as well as provide security and CCTV in a widely distributed set of assets utility providers will use wireless communications services. In future spectrum enabled communications will support Smart Grids which will connect many more devices and equipment to electricity networks. In that regard, ComReg is currently consulting on the future use of the

400 MHz, including limiting 2 × 3 MHz rights of use for Smart Grid to Network Utility Operators.[43]

In the absence of spectrum, the cost of maintaining and monitoring networks could significantly increase as utility providers would have to rely on wired technologies.

Logistics

The industry of logistics have adopted a number of different spectrum enabled technologies which increase efficiency. There are a number of different uses. Navigation tools enable logistics firms to deliver more efficiently. Tracking and identification enable parcel tracking so consumers and firms can track packages "live". Mobile telecommunications enable enhanced customer communications. Sensor monitoring and environmental control enables logistics firms to more efficiently supply perishable and environmentally sensitive goods.

Logistics

Logistics use spectrum for tracking and navigation.

The use of wireless technologies enable more efficient supply chains and enhanced customer value.

Farming

There are many wireless applications that can be used to increase efficiency in the agriculture sector. Sensors can be used to monitor and measure various aspects of animal husbandry and arable faming to improve yield and reduce costs. Monitors can measure everything from soil moistures to food intake for livestock. Measurements can then be analysed to automate provision of water, food or fertiliser.

Farming

Agriculture uses spectrum for monitoring to improve yield.

All these technologies support cost efficiencies (lower costs of fodder or fertiliser) and higher yields.

4.2 Consumer surplus associated with use of spectrum

Consumer surplus associated with the use of spectrum represents the private increase in welfare that users enjoy as a result of the consumption of goods and services where spectrum is an input. In economic terms, where users value the good or service in question more than they pay for the service they enjoy a consumer surplus.

[43] Document 18/92, "Further Consultation on the Release of the 410 - 415.5 / 420 - 425.5 MHz Sub-band"

Section 2.2 of the methodology consultation[44] noted that in theory it is possible to estimate the amount of consumer surplus associated with consumption of goods and services. For instance, consumer surplus could be estimated by using assumptions on the nature of demand[45].

However, as stated in the consultation there are a number of reasons why, in practice, it would be difficult to calculate this accurately. An assessment of consumer surplus is very sensitive to the assumptions made on the nature of demand: such as the shape of the demand curve (whether linear or log-linear), and the “choke price” (i.e. the price at which demand is zero). Furthermore, estimating consumer surplus would be more difficult to implement in those sectors (such as broadcasting) where revenues are derived from advertising (in a two sided market). This is because in these markets the price that consumers pay is zero, and therefore estimating the shape of the demand curve is problematic.

Therefore, the methodology consultation did not propose to measure consumer surplus. However, we note that spectrum produces benefits which enhances consumer welfare, and for this reason our estimates of direct GVA using Approach 1 will underestimate the total economic value associated with consumption of the goods.

4.3 The “social value” of goods and services that rely on spectrum

The benefits arising from the use of the spectrum is not limited to the private benefits accrued in the supply and consumption of goods and services that use spectrum, or to the impact on economy wide productivity. There are a number of sources of *social value* that are related to the use of goods and services that rely on spectrum. These include, for example, the contribution that spectrum makes to social capital via supply of public service broadcasting, or its role in contributing to public security via its role in emergency communications, or more generally enhancing social cohesion and mitigating geographic inequalities by improving communications.

While quantitative estimation of these effects is beyond the scope of this study, they should be borne in mind when considering the gross economic contribution that spectrum makes to the Irish economy.

In assessing the economic impact of goods and services that use spectrum it can be relevant to consider the social value associated with their consumption. Social value can be defined as the impact on “social goods”. These could include social goods which have value to society, though may not be traded.

Some examples are set out below.

[44] ComReg Document 18/74a.

[45] Studies which set out the elasticity of demand for mobile services could be used to estimate the consumer demand curves

Where consumption of spectrum related services (such as mobile communication, social networks, broadcast services, transport) support the creation and maintenance of social capital they can increase social value.

Social capital

Supporting social networks and communities

Our social (and economic) relationships rely on trust and security. Underpinning our notions of security are the various institutions and investments in public and private investments in security. To the extent that these rely on spectrum (for communications or monitoring for example) they enhance social value.

Security

Supporting emergency response and public order

Consumption of culture can increase the welfare of society, for example, by creating shared values and understandings that facilitate cooperation. Therefore, where consumption of spectrum related goods and services support access to social welfare enhancing aspects of culture, this will also be an economic benefit.

Culture

Supporting creation of “cultural capital”

Spectrum can play a role to ameliorate economic or social inequalities as a result of greater access to communication or geographic dispersal of economic activity may add to a country’s social value by increasing access and opportunity.

Inequalities

Mitigating social or geographic inequalities

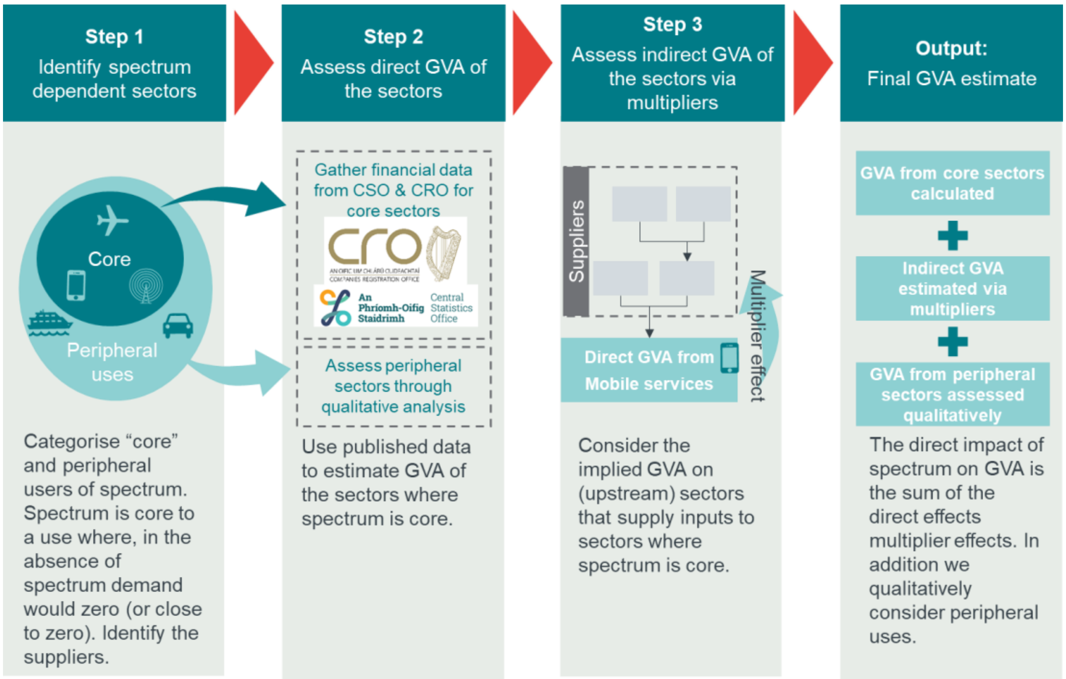
ANNEX A METHODOLOGY FOR MEASURING THE VALUE ADDED OF FIRMS THAT DIRECTLY USE SPECTRUM

Method 1 estimates the contribution that spectrum makes to the Irish economy by identifying the economic value added in sectors where spectrum is a core input to the supply of goods or services.

This is done in the following three steps.

- Step 1: Identify sectors where spectrum is a "core" input to the supply or demand of the good or service.
- Step 2: Estimate the direct economic activity (value added) associated with the sectors identified in the financial years 2013-2016.
- Step 3: Estimate the indirect impact of the economic activity associated with step 2.

Exhibit 1. Illustration of methodology to measure the direct impact



Source: Frontier

A.1 Step 1: Identify sectors where spectrum is "core" to the supply or demand of the good or service

The use of spectrum in the production of goods and services can vary significantly for different sectors, with some sectors being more reliant on spectrum than others. For certain sectors, spectrum is an essential input and there are no substitutable inputs in the absence of the spectrum. Without spectrum, these sectors would not be able to produce those goods and services.

The sectors where spectrum is a "core" input is set out in Table 1. These are economic activities where in the absence of spectrum, economic output would be zero or close to zero[46,47].

Table 1: Identified Target Sectors

Sector	Rationale for inclusion
Operation of mobile services	Mobile services clearly rely on spectrum to support mobile communication services. Mobile network operators provide mobile services (such as calls and data) which are entirely dependent on the use of spectrum.
Manufacture, Sale and Distribution of Mobile Devices	The manufacture, sale and distribution of mobile devices are activities generated by the demand for mobile hardware to enable spectrum transmission.
Satellite Communications Services	Satellite services provide connectivity using a combination of ground based stations and space satellites. They provide services ranging from high-speed internet access, to mobile television or radio, and public protection and disaster relief. Satellite services are entirely dependent on the use of spectrum.
Fixed Wireless	Fixed wireless technologies use spectrum in transmitting information between wireless links. Fixed wireless services are entirely dependent on the use of spectrum.
Professional Mobile Radio	Spectrum based mobile communication services often used by police forces and fire brigades, as well as certain commercial sectors. Professional Mobile Radio services are entirely dependent on the use of spectrum.
Aviation	Aviation relies on spectrum for specialist communication, safety, data broadband links, and navigation. The aviation industry will be significantly diminished in the absence of spectrum.
Radio and Television Broadcasting	Radio and Television broadcasting relies on spectrum to transmit its live stream of audio / audio-visual information. Radio and Television Broadcasting services are currently dependent on the use of spectrum to distribute content to end users via satellite, terrestrial and mobile (though of course cable and fixed broadband also distribute TV and radio services).
Mobile Content Creation and Advertising	Content creators and advertisers who are solely based on the development of mobile contents and advertising. There will be no demand for their services in the absence of spectrum.

Source: Frontier

Within each sector we identify the key suppliers of products and services that rely on spectrum. These companies include:

- Companies assessed by ComReg as relying on spectrum in its previous analysis.

46 This analysis excludes the contribution that spectrum makes in sectors where it is not "core" to the supply. In this way the analysis will underestimate the economic contribution of spectrum

47 These sectors are mapped to NACE codes, which classify economic activities used by National Statistics Agencies. NACE is a four-digit classification providing the framework for collecting and presenting a large range of statistical data according to economic activity in the fields of economic statistics (e.g. production, employment and national accounts) and in other statistical domains developed within the European statistical system (ESS).

- A review of firms who identify their activities as a NACE code which is related to spectrum (for example NACE Code 61.20 wireless telecommunications).

The analysis also considers whether there are a range of ancillary economic activities which do not rely on spectrum directly but which support spectrum related activities. These could be supply of mobile applications and content, and or supply of mobile advertising.

A.2 Step 2: Estimate the direct economic activity associated with the sectors identified

The analysis estimates the direct economic activity associated with the sectors identified (GVA, employment). We use company data, though this may underestimate the contribution of spectrum to modified Gross National Income[48] (GNI) as it does not account for:

- Small businesses whose information does not appear on Company Registration Office data or national accounts; and
- Companies for which spectrum is an important input but whose activities would still take place without spectrum.

However, this data source enables estimates of economic activity at granular sub-sectors of the economy in a way that is not possible with national accounting measures.

Furthermore it would exclude the value of spectrum produced outside Ireland (even when consumed in Ireland – for example when calling overseas).

Measuring GVA

Gross value added (GVA) is defined as output (at basic prices) minus intermediate consumption (at purchaser prices). It can be used to measure output in a given sector. We propose to use the "income approach" to measuring GVA in a given sector.

[48] Modified GNI (or GNI*) is defined as GNI less the effects of the profits of re-domiciled companies and the depreciation of intellectual property products and aircraft leasing companies. This new indicator of the level of the Irish economy will be a useful additional input to debt ratio analysis. Modified Total Domestic Demand is defined as Total Domestic Demand less the effects of the trade in aircraft by aircraft leasing companies and the imports of intellectual property. This modified indicator gives insight into the activity within the domestic economy and is designed to be more closely related to employment growth as it is focuses on the physical capital used to produce domestic output.

MEASURING GVA

GVA can be calculated through either the income or production approach.

Income approach

GVA at basic prices = Gross operating surplus + compensation of employees + compensation of those self-employed

GVA at market prices = Contribution to GDP = Gross operating surplus + compensation of employees + compensation of those self-employed (mixed income) + taxes on products – subsidies on products

Gross operating surplus is effectively equal to the sum of gross trading profits and income earned through the ownership of buildings (rental income).

Compensation of employees is the sum of all employment incomes, pensions, National Insurance contributions, bonuses and benefits.

Mixed income accounts for the income of those self-employed, which consists of both salary and profit.

Production approach

GVA at basic prices= Output – intermediate consumption

GVA at market prices = Contribution to GDP = Output – intermediate consumption + taxes on products – subsidies on products

Output comes in two types:

- Market output, which represents goods and services and are sold by a price such as by corporations, and these can be measured as total sales plus changes in inventory.
- Non-market output, which represent goods and services that have no meaningful selling price such as those given by governments or non-profit institutions, and the value for this is approximated by summing labour costs, intermediate costs and depreciation of assets.

Intermediate consumption is defined as all goods and services used up or transformed in the production process, such as raw materials, fuel, rent and advertising, but importantly excludes staff wages and capital investment.

In practice, the analysis will use company data from companies' annual accounts, obtained from the Companies Registration Office (CRO). To be consistent with the income approach of measuring GVA at market prices, we sum:

- operating profit (EBIT);
- depreciation, amortisation and impairment;
- production taxes minus subsidies;
- total staff costs (including national insurance contributions, pensions etc.); and
- taxes minus subsidies on products.

Net taxes and subsidies on products are usually not available in companies' financial statements. We therefore estimate these using national accounts data.

A.3 Step 3: Estimate the indirect supply impact of the economic activity associated with step 2

We use a "multiplier approach" to assess how activity in sectors where spectrum is directly used affects activity in related upstream markets. For example, a given incremental €1 output in one sector (in a downstream market) could lead to output in the upstream markets which supply inputs to produce the incremental output (for the downstream market).

WHAT IS THE MULTIPLIER EFFECT?

The **total economic impact** of additional economic activity in one sector comprises two effects: the **direct effect** and the **multiplier effect**.

The **direct effect** is an increase in output in the economy as a result of a change in final demand in a sector – additional activity in a sector such as increased use of mobile devices will lead to an increase in output in the economy, for example.

The **multiplier effect** measures the indirect impact that incremental economic activity in a sector generates. There are two types of effects:

- Indirect Effect: the additional expenditure in the sector's supply chain, following the incremental activity within the sector. Those in the upward supply chain will purchase more goods and services– leading to an additional increase in output in the supply chain.
- Induced Effect: the income effect of hiring more workers to meet an increase in final demand. As these workers gain greater income, there will be additional household expenditure on goods and services that would not occur if not for the initial increase in activity in the sector.

In Ireland, the CSO publishes input output tables and estimates associated output multipliers from which it may be possible to measure the indirect effect that incremental activity in one sector can have the wider economy. In doing so the CSO estimates the direct *plus* indirect effect on other inputs per €1 of final demand. The CSO estimates coefficients on each of (i) imports, (ii) taxes less subsidies, (iii) compensation of employees, (iv) consumption of fixed capital and (v) net operating surplus, which show how €1 of final demand in a given sector is distributed across the economy (after all cycles of production). From these estimates it is possible to estimate the GVA (including direct and indirect effects) associated with €1 of final demand in a given sector. CSO notes that:

> *"… the sum of the coefficients of imports, taxes less subsidies, compensation of employees, consumption of fixed capital and net operating surplus add to 1. They show, after all the cycles of production are completed, how the additional unit of final demand* [in a given sector] *was spread over these categories* [across the whole economy]*. There is no duplication in these coefficients."*[49]

These coefficients enable us to estimate the sum of direct and indirect GVA of given level of final demand.

[49] See: https://www.cso.ie/en/media/csoie/releasespublications/documents/ep/supplyandusetables-current/2014/Supply_and_Use_Tables_-_Overview_slides.pdf

Multiplier analysis is widely used. However, there are a number of caveats to its use which should be borne in mind when interpreting the results.

- Firstly, while multiplier analysis can be suggestive of the indirect upstream impacts as a result of economic activity in a downstream market, it can lack transparency and be difficult to calculate robustly for very granular subsectors of the economy. Therefore, while we include it within our analysis our focus is on estimating the direct impact.
- Furthermore, we note that the most recent multipliers available from the CSO are from 2015[50], and the structure of the Irish economy may have changed significantly since then.

[50] At the time of this analysis.

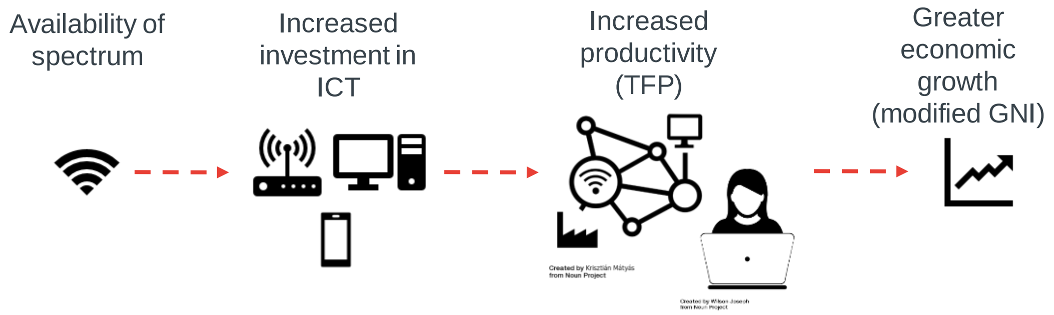
ANNEX B METHODOLOGY FOR MEASURING THE CONTRIBUTION OF SPECTRUM TO PRODUCTIVITY

B.1 Introduction

The availability of radio spectrum supports the digitalisation of the economy, now widespread across virtually all industries. Digitalisation does not appear to have (yet) led to a radical change in the speed of productivity growth in advanced economies. However, there is a substantial body of empirical evidence showing that, in many cases, increasing investment in, and use of, ICT has been a key driver of productivity growth since the mid-1990s.[51]

Figure 17 below illustrates how spectrum can lead to greater economic growth through its role as enabler of investment in ICT equipment.

Figure 17 Stylised representation of links between spectrum and productivity growth



As communication becomes cheaper and instantaneous, firms can organise production in ways that would not have been possible before – for example, exercising more choice about when to delegate responsibility to local teams, or to increase the responsibility of central teams. These effects are specific to ICT equipment: other forms of capital (for example, buildings or plant machinery) have not been linked to higher TFP.

Therefore, if spectrum enables investment in ICT that would not have happened otherwise, we would expect this to determine higher TFP. This would still be the case even if the additional spectrum-related ICT investment came at the expense of investment in other forms of capital.

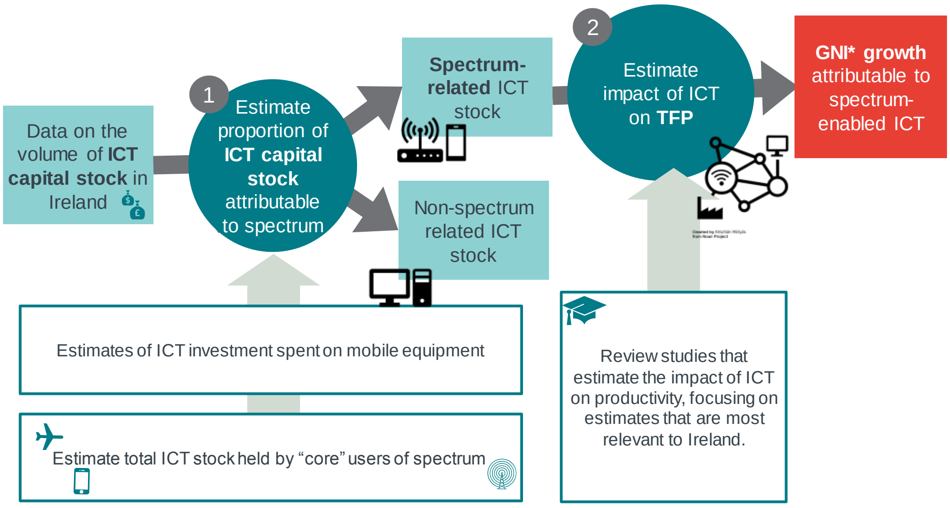
Assessing the impact of spectrum related ICT investment within the broader category ICT investment allows us to rely on a number of existing studies which estimate the likely impact of ICT investment on productivity. Figure 18 below

[51] Van Reenen et al. (2010) provides an overview of the findings from this literature as well as original research on the impact of ICT; Stanley et al. (2018) provides a meta-analysis including 466 estimates drawn from 59 econometric studies.

illustrates our overall approach to conducting this assessment, which consists broadly of two steps:

1. Estimating the change in ICT equipment (technically, capital stock[52]) as a result of spectrum related investments; and
2. Using existing studies to obtain an estimate for the impact of ICT on productivity in Ireland and applying this to the proportion of ICT capital stock in Ireland related to spectrum.

Figure 18 Overview of our approach



In principle, an alternative approach could be to rely on studies that directly estimate the impact of mobile broadband on economic output. We choose to rely on studies on ICT capital as they allow us to focus on TFP as a measure of productivity.

B.2 Step 1: Estimating the change in ICT capital stock as a result of spectrum related investments

In each year, investment in spectrum-related equipment contributes to the overall stock of ICT capital in the economy. We estimate investments in spectrum equipment made over three years (2013-15) mean that (the real[53] value of) the ICT capital stock at the end of the period (2015) is 16% higher than it would have been otherwise. This is equal to EUR 790 million out of the total (real value of) the Irish ICT capital stock, 5.6 billion as of 2015, the most recent year for which these data are available.[54]

We have estimated this as follows:

[52] The capital stock is derived from Eurostat data and includes all ICT capital stock, including government-owned and fixed; then the proportion that would not exist without spectrum is based on private investment in mobile technologies.

[53] All figures used in this calculation are at constant 2010 prices, and therefore are not influenced by inflation.

[54] In 2015 prices, this would be EUR 940 million out of a total value of the Irish ICT capital stock of EUR 5.76 billion. Source for total ICT capital stock value: Eurostat.

- First we looked for available data on the proportion of telecommunications investment in Ireland that is related to wireless technology, which is estimated at 44%.[55]
- We then compute how much lower the total ICT stock in Ireland would be if telecommunications investment in that year was 44% lower. In this 'counterfactual' scenario with no spectrum-related ICT investment, ICT stock in year 2 would equal:
  - ICT stock in year 1;
  - Minus depreciation of the ICT stock occurring between year 1 and 2;[56]
  - Plus ICT investment in computing and non-spectrum related telecommunications capital.[57]
- The impact of spectrum-related investment on the ICT capital stock is then the difference between the actual ICT capital stock in the end year (e.g. EUR 5.6 bn in 2015, at constant 2010 prices), and the counterfactual ICT capital stock with no spectrum-related investment calculated as above.

The proportion of Telecommunications investment in Ireland that is related to wireless investments is measured using the most recent data on investment in network infrastructure collected by the International Telecommunications Union (ITU). ITU collect data on the investments made by 'entities providing telecommunication networks and/or services' for 'acquiring and upgrading property and networks within the country', excluding expenditure on fees for operating licences and the use of radio spectrum.[58] The latest year available in these data is 2009, when the total amount of mobile network infrastructure was valued at US$ 614m, of which US$ 272m (44.4%) invested in mobile services. We recognise that this assumption relies on data that is over ten years old and pre-dates investments in 4G mobile networks and investments and upgrades in fixed networks. However, we are not aware of a more recent estimate.

Ideally, our assessment should reflect the possibility that non-spectrum related ICT investment may have been higher if spectrum was not available. This is because, as firms and individuals could not have used mobile communications, they might have invested more in other forms of ICT. However, we did not identify any source of data that would allow us to 'net out' this effect from the estimated increase in ICT capital stock over the last three years (we estimate above that the ICT capital stock is 16% higher [59] as a result of investments in wireless technologies).

This may imply that the estimate of the increase in the value of the ICT capital stock overestimates the true increase ICT investment attributable to spectrum related investments. However, this is offset at least in part by our assumption that only mobile communications capital is related to spectrum. This is a conservative assumption that likely underplays the role of spectrum: this is because it is likely that a significant proportion of computing equipment would not be installed without

[55] Effectively, this calculation assumes that the only form of ICT capital stock attributable to spectrum is mobile communications equipment.

[56] Measured as total ICT fixed assets net of disposals, valued at replacement cost.

[57] Technically the measure of investment use is Gross Fixed Capital Formation.

[58] Source: ITU.

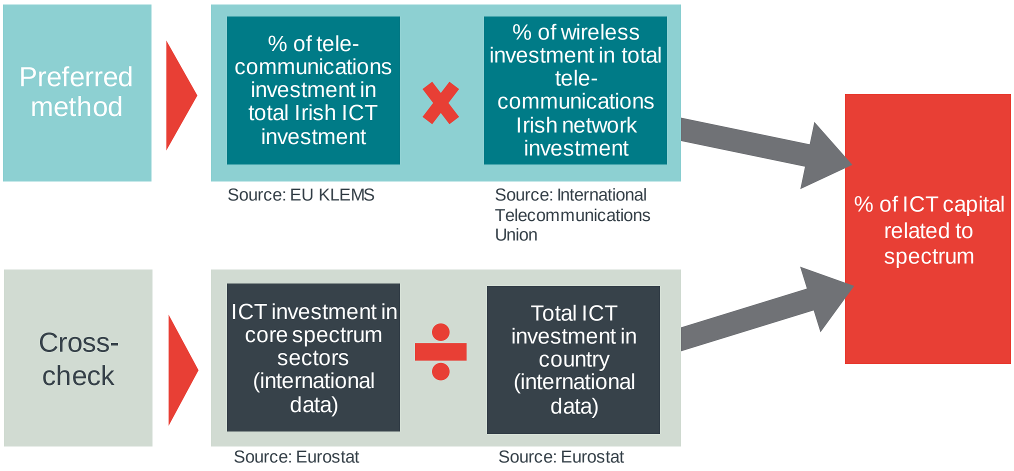
[59] 44% * 37% equals 16%

spectrum. For example, many of the data on consumers analysed in marketing departments across a wide range of industries are collected thanks to consumers using mobile devices to browse the internet and shop online; more in general, the utility of laptops would be lower if they could not rely on wireless connectivity.

Step 1 – Cross-check using international data

Given the need to rely on a proxy for the proportion of ICT capital stock that is due to spectrum-related investment in the approach described above, we also tested an alternative method for this step of our analysis, illustrated in Figure 19 below.

Figure 19 Alternative methods to compute the proportion of ICT stock related to spectrum



Source: Frontier

To derive an estimate using this approach we would need data on ICT stock by sector for Ireland, which are not available. However, applying this method with international data can still be useful to check whether our preferred 16% estimate is very far off a likely lower bound for the proportion of ICTcapital stock that is due to spectrum-related investment. Using data from the UK, adjusted to reflect the industrial composition of the Irish economy, we estimate that the likely lower bound for the total Irish ICT stock attributable to investment in core spectrum sectors is 12%. In the Results section of this note, we therefore show how our estimate of the impact of spectrum on productivity would change if the proportion of ICT stock related to spectrum was between 12% and 16%.

B.3 Step 2: Measuring the link between ICT equipment and productivity change

We have reviewed the economic literature on the relationship between ICT capital and productivity. We estimate that a 10% increase in the ICT capital stock in Ireland can lead to an increase in economy wide productivity (technically, Total Factor Productivity) of 0.17 percentage points. This is the median across all the estimates from studies of the impact of ICT we have collected, listed in Figure 20 below. Increases in productivity then translate directly into an equal impact on the annual growth rate of GNI*.

We set out below:

- Our approach to the literature review;
- A summary of the estimates from the literature;
- Cross checks with estimates of ICT and other measures of economic output;

Approach to literature review

In this analysis, we focus on productivity defined as Total Factor Productivity (TFP), which measures how efficiently an economy combines its inputs (labour and capital) to generate output. This is for two reasons:

1. Differences in TFP are more important in explaining long-run differences in economic growth over time and between countries than differences in the quantity or quality of inputs (see for example Hall & Jones, 1999);
2. Focusing on TFP allows us to focus on the additional effect of ICT equipment on top of what might be achieved through other investments. Investment in any form of capital leads to greater productivity, measured as output or GVA per worker. However, there is evidence that ICT capital has an additional impact compared to other forms of capital – its impact on TFP.

To estimate the likely impact of ICT capital on productivity growth, we carried out a review of the available literature, including:

- Academic working papers and articles published on peer-reviewed journals;
- Studies published by public sector institutions in the UK and internationally;
- Research undertaken by organisations within the communications sector and industry analysts.

We restricted our search to studies published in the last 15 years that provide robust quantitative estimates of the impact of ICT investments. These estimates are typically obtained by comparing productivity growth in countries or firms that use varying levels of ICT capital.[60] Restricting the scope of our analysis to robust econometric studies excludes:

- ‘Growth accounting’ studies, which observe what proportion of total productivity growth has taken place in industries which produce ICT equipment (e.g. Manufacture of computers, computer programming) and industries which use ICT (typically including Finance, Research & Development and other Professional Services, among other sectors);
- Studies providing simple correlations between ICT use and productivity, not controlling for any other possible factors.

Having completed our review, we have also excluded estimates based on data from the United States (US). This is because there is robust evidence that the impact of ICT on productivity has been larger in the US than in Europe, and

[60] For the purposes of this report, we define as ‘robust’ estimates that use econometric methods to credibly control for other factors that may be driving the relation between ICT capital and productivity. For example, if better-managed firms also use more ICT, a simple comparison between firms that use more and those that use less ICT would overestimate the impact of ICT on productivity – the estimated impact would reflect not only the role of ICT but also the role of good management.

therefore using US figures would have likely led us to overestimate the impact of ICT investment on productivity in Ireland[61] .

We list the studies that we have used and resulting estimates in Figure 20 below. Having excluded US studies from our sample, we focussed on European studies which provided or allowed us to infer the estimated impact of ICT on TFP – specifically, the additional TFP growth associated with a 10% increase in ICT capital.

Figure 20 Studies estimating the impact of ICT capital on TFP in Europe

Study	Geography	Time period	Impact of 10% increase in ICT capital on TFP (percentage points)
Van Reenen (2010)	13 EU countries (excluding Ireland)	1999-2008	0.07
van Leeuwen and van der Weil (2003)	Netherlands	1994-1998	0.079
Spiezia (2012) (Table 2)	18 OECD countries (including Ireland)	1995-2007	0.17
Frontier Economics (2011) – lower estimate	UK	1980-2007	0.47
Frontier Economics (2011) – higher estimate	UK	1980-2007	0.58

Estimates based on the UK from Frontier Economics (2011) are significantly larger than others reported in Figure 20, and in line with typical estimates for the US. It is possible that the UK has benefitted from ICT more than other European countries, as also noted by Van Reenen et al. (2010), but other studies conclude that this was not the case (e.g. Bloom et al., 2012). Therefore we retain UK studies in our sample.

Our preferred estimate of the impact of ICT capital on TFP in Ireland is that provided in the study by Spiezia (2012): 0.17 percentage points of additional TFP growth resulting from a 10% increase in ICT capital. We focus on this estimate for two reasons:

- Spiezia (2012) is the only study that includes Ireland in its sample;
- This is the median among the estimates summarised in Figure 20, and very close to the median including the implied estimates reported in Figure 21.

[61] O'Mahony & Vecchi (2005) and Van Reenen et al. (2010), among others, estimate the impact of ICT using data from both the US and other countries, and find the impact to be larger in the US. Bloom, Sadun & Van Reenen (2010) also find that US multinationals based in Europe benefitted more from ICT than European firms with local owners

Cross checks with estimates of ICT and other measures of economic output

We note that this is a relatively small portion of the available literature on the impact of ICT. This is because we exclude not only studies based on the US (as noted above) but also those studies that estimate the impact of ICT on outcomes other than TFP (including GVA and GDP) and output per worker. In this regard it is worth noting that the estimates we have excluded typically indicate somewhat larger effects of ICT – for example, the meta-analysis provided by Stiroh (2002) reports that the median estimate of the impact of a 10% increase in ICT capital on output across 20 econometric studies is 0.46 percentage points.

As a cross-check, we therefore also consider four more studies that estimated the impact of ICT on a different measure of productivity, output per worker. We infer the likely size of TFP effects implied by their estimates, reported in Figure 21 below. These additional estimates are consistent with the median estimate in Figure 20, used to produce our central estimate of the impact of spectrum on productivity.

To infer the TFP effects implied by these studies, we calculate the ratio between TFP effects and output per worker effects in Spiezia (2012) and Van Reenen et al. (2010)[62], which estimate the impact of ICT capital on both measures of productivity. The ratio between TFP effects and output per worker effects in both these two studies is around 30%.[63] TFP effects reported in the rightmost column of Figure 21 below are obtained multiplying the impact on output per worker reported in the studies (second column from the right) by 30%.

Figure 21 Studies estimating the impact of ICT capital on output per worker in Europe

Study	Geography	Impact of 10% increase in ICT capital on output per worker (percentage points)	Implied impact of 10% increase in ICT capital on TFP (percentage points)
Bloom et al. (2012)	UK	0.15	0.05
Hempbell (2005a)	Germany	0.41	0.12
Hempbell (2005a)	Germany	0.22	0.07
Hempbell (2005b)	Germany	0.49	0.15
Hempbell (2005b)	Germany	0.60	0.18
Venturini (2009)	EU-15	0.94	0.29

In the Results section of this note, we show how our estimate of the impact of spectrum on productivity would change if we used a lower estimate (in the range of 0.07 percentage points as in Van Reenen et al. 2010) or a higher estimate (in

62 The ratio of the two estimates is expressed as: the impact of ICT investment to TFP as a percentage of the impact of ICT investment on labour productivity.

63 The exact ratios are 0.17/0.56 = 30.3% for Spiezia (2012) and 0.07/0.23 = 30.4% for Van Reenen et al. (2010).

the range of 0.23 percentage points, a cut-off point which is above 75% of the estimates reported in Figure 20 and Figure 21).

B.4 Step 3: Generating estimates of the impact of spectrum on productivity

We generate our estimate of the impact of spectrum on Irish GNI* in 2016 through productivity growth as follows. we multiply the change in ICT capital which is as a result of investments in spectrum (Step 1) by the impact of additional ICT on productivity (Step 2) and the level of Irish GNI* in 2015.[64] This effectively estimates the proportion of growth in Irish GNI* that can be attributable to investments made in spectrum related capital over the period.

Alternatives to our base estimate have been generated by varying our preferred estimate of:

- Input 1: the proportion of ICT stock that is related to spectrum ('spectrum to ICT impact', Step 1 of our calculation); or
- Input 2: the impact of ICT stock on annual TFP growth.

Figure 22 below shows how impact estimates vary according to alternative choices around input 2.

Figure 22 Alternative modelling inputs

Estimate	Input 1: Additional ICT capital due to spectrum (% of total ICT stock)	Input 2: Additional TFP growth due to 10% ICT capital increase (percentage points)	Impact of spectrum on GNI*, 2016 (EUR m)
Lower impact of ICT stock on TFP	16%	0.075	196
Base case	**16%**	**0.17**	**447**
Higher impact of ICT stock on TFP	16%	0.23	615

Source: *Frontier Economics calculations based on data from CSO and Eurostat, and on economic literature summarised in Section 3.2 of this report.*

Our choice of alternative inputs is as follows:

- The lower case (0.075) is at the first quartile of all available estimates – that is, 75% of all available estimates are above 0.075;
- The higher case (0.23) is at the third quartile of all available estimates – that is, 75% of all available estimates are below 0.23.

Because our estimate of the proportion of ICT investment due to spectrum relies on relatively old data on mobile investment (data on 2009 from ITU), we also check how our impact estimates would vary with a different estimate for this input. Using the alternative method described under Step 1 above, we estimate that three years of spectrum-related investment lead to a 12% increase in the ICT capital stock.

[64] We use 2015 GNI* to compute the impact in 2016 because we measure of the effect of spectrum on annual productivity growth between 2015 and 2016.

Using this estimate for Step 1, and our central estimate of the impact of ICT capital stock for Step 2, we would estimate the impact of spectrum on Irish GNI* in 2016 at EUR 335m. This is likely to be an underestimate of the contribution of spectrum, because it only accounts for the impact of spectrum-related investment in core spectrum sectors.

B.5 References

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ANNEX C RESPONSES TO COMREG'S CONSULTATION - METHODOLOGY FOR MEASURING THE ECONOMIC CONTRIBUTION THAT SPECTRUM MAKES TO IRISH ECONOMY

On 3 August 2018 ComReg published its Proposed Strategy For Managing The Radio Spectrum 2019 - 2021 [65]. As part of this report ComReg consulted on a methodology for measuring the economic contribution that spectrum makes to Irish Economy[66]. ComReg proposed two complementary methodologies:

1. To measure the direct and indirect contribution that spectrum makes to the economy; and

2. To assess the impact of spectrum related investments on productivity.

ComReg's proposed methodology was informed by a report by Frontier Economics which it published alongside its consultation ("the Frontier Report")[67].

This note comments on the responses that ComReg received to its consultation which relate to the proposed methodology for measuring the economic contribution that spectrum makes to the Irish economy.

There were a number of responses to the methodology consultation relating to:

- Secondary users of spectrum
- Social value of spectrum
- Other comments

C.1 Secondary users of spectrum

Consultation comments

Certain respondents submitted that ComReg's proposals would not comprehensively include the economic value derived from secondary users of spectrum. For example, ESBN noted that it was a *user* of spectrum for its (internal) fixed wireless links, and stated that it was the 10th biggest user of fixed links in Ireland. It noted that this infrastructure supported its ability to provide "*a reliable, efficient and safe electrical supply to all customers*". It therefore suggested that the economic estimates include benefits derived from sectors of the economy *"that are*

[65] See ComReg 18/74 https://www.comreg.ie/publication/proposed-strategy-for-managing-the-radio-spectrum-2019-2021/

[66] See ComReg 18/74 section 6.

[67] See ComReg 18/74a https://www.comreg.ie/publication/frontier-report-measuring-the-economic-value-of-spectrum/

secondary users of spectrum in terms of their business model". Similarly Joint Radio Company (JRC) also noted that the value created by secondary users of spectrum was relevant "*i.e. those that utilise spectrum as a key enabler of their operational capability. e.g. communications systems improve efficiency and costs and can be critical to safe management and operation of supply systems (energy networks)."* Specifically it noted that the utility sector was a key user of spectrum both currently and more so in the future "*in light of the increasing importance of robust and resilient operational telecommunications systems to the Utility sector*".

Frontier response

The Frontier Report recognises the importance that spectrum and spectrum related services has for "secondary users". Secondary users are those users that use spectrum as an input in supplying goods and services which are not directly related to wireless communications[68]. These include but are not limited to electricity distribution networks such as ESBN. Though the analysis will consider the contribution that ESBN's *telecommunications* activities that rely on spectrum (for example provision of fixed wireless, and services which rely on its management of its network of transmission towers) it does not directly estimate the contribution that spectrum makes to "secondary" users of spectrum such as ESBN (i.e. where it is an input, but not a core input).

However, the second methodology proposed by ComReg estimates the impact that investments in wireless networks could have on Total Factor Productivity. This will partly reflect the incremental economic value that is derived from secondary users of spectrum services (i.e. those that invest in spectrum related ICT capital). This approach will therefore capture the productivity benefit to whole economy of such investments in spectrum. However, we recognise that even this approach will not identify all benefits from secondary users for a number of reasons: the estimates of spectrum related ICT capital may not fully identify all spectrum related ICT capital; and the approach identifies *economy wide productivity impacts*, which may not reflect contribution to private value of secondary users of spectrum.

As noted in the Frontier Report, we considered that within the scope of this study there was no robust way to either exhaustively identify all secondary users of spectrum, nor to weight the GVA created by secondary users according to the contribution that spectrum makes to their economic output (as distinct from other inputs). Therefore we have not amended the scope of the analysis to include secondary users, but agree that when interpreting the results of the analysis it should be recognised that the contribution of spectrum to the economy would be *higher* if the value from secondary users could be fully included.

C.2 Social value of spectrum

Consultation comments

ESBN submitted that there were social impacts related to the use of spectrum which could be considered (for example public services or emergency services).

[68] In the Frontier Report we noted that in these cases spectrum was not a "core" input.

Similarly JRC submitted that spectrum used for "*broadcast services that inform, educate and support communities and cultural identity*" creates social value.

Frontier response

We agree that the social value which is derived from goods and services that rely on spectrum is relevant when considering its economic value. However, there are methodological challenges to quantifying this social value. First, there are practical difficulties in identifying and quantifying the utility that users derive from incremental social value which is enabled by spectrum (for example the value that users derive from enjoying communities and social networks supported by spectrum; or the value that users derive from enjoying defence and security). While there are different methodological tools that can be used to estimate users social value (surveys on stated utility or subjective wellbeing), these are complex and beyond the scope of this report. Second, much of the social value related to spectrum relates to positive economic "spill over" social impacts. These are benefits that accrue to society at large, (not just to the specific users of the goods and services that support social value). Identifying and measuring the spill over impacts is complex.

But we nonetheless acknowledge that this report does not exhaustively include all potential economic impacts of spectrum. Therefore, while the economic value of such spectrum may be difficult to measure, the social benefits of spectrum can be qualitatively described.

C.3 Other comments

Consultation comments

eir agreed that the combination of the methods to measure both direct and productivity impacts would be appropriate.

eir also suggested that ComReg could commission a survey to augment the analysis.

Frontier response

In relation eir's suggestion that ComReg could commission a survey of users of spectrum to augment the analysis, we note that views of industry stakeholders are important to ComReg, and that the consultation on the draft Spectrum Strategy provides an opportunity for industry stakeholders to provide views of users of spectrum.

The use of surveys would provide valuable evidence on how spectrum is used across different users, however, its use for this assessment is not necessary in order to estimate the added value provided by firms who use spectrum as a core input because such detailed information is already available from the CSO and CRO.

www.frontier-economics.com