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Can an information and communication technology (ICT) satellite account help us to understand digital sovereignty?

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ABSTRACT

The concept of 'digital sovereignty,' relating to a nation or region's ability to assert control over its digital infrastructure, data, and capabilities, is increasingly embedded in strategic policy towards key parts of the information and communication technology (ICT) industry. However, there are few tools available that enable us to better understand the interconnections and interdependencies between supply and use of ICT products and services in an economy, as well as dependence on externally produced ICT goods and services. This paper investigates how an ICT satellite account can provide valuable insights across various industries and products. We employ satellite accounting methods to identify key elements of the significance of the ICT industry and show that such an accounting framework might inform debates over digital sovereignty.

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KEYWORDS
ICT industry; digital sovereignty; Welsh economy; satellite accounting

1. Introduction

In economies across the globe, the concept of 'digital sovereignty' has become increasingly debated but is being increasingly embedded in strategic policy towards key parts of the Information and Communication Technology (ICT) industry. This is most explicitly seen in the US Chips Act of 2022 (US Department of State, 2022) and with similar interventions occurring in China, Korea and in the European Union (see for example, European Commission, 2022; see also House of Commons, 2022; Johnston & Huggins, 2022, 2023). The United Kingdom (UK) has also moved to directly support the semiconductor industry, with aims described in the UK National Semiconductor Strategy (Department for Science, Innovation and Technology, 2023). This UK development follows well publicised issues with potential foreign involvement in national telecommunications infrastructure, notably that of Huawei in 5G (see King, 2019; Schmitz & Seidl, 2022; see also Global Counsel and Imagination, 2022), and then the direct involvement of the UK Government in the case of Newport Waferfab (in South Wales) following its takeover by a Chinese owned group, Nexperia.

Jansen et al. (2023) show that digital sovereignty can be understood in terms of the ability to assert control over digital infrastructure, data, and capabilities. The increasing

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use of the term reflects the concerns of citizens, businesses, and nations over a real or perceived loss of control over innovation, legislation shaping, and enforcement ability in the digital environment (Madiega, 2020). From a European Union perspective, adding to concerns over digital sovereignty has been that the digital infrastructure supporting governmental services and daily life is increasingly reliant on 'Big Tech' overseas businesses, including Apple, Amazon, Google, and Huawei (Farrand & Carrapico, 2022; see also Bellanova et al., 2022; Perri & Andersson, 2014; Van Dijck et al., 2018). Digital sovereignty is also seen as a political order that promotes digital policies to increase control of the digital, including physical, code, or information layers, specifically on infrastructure, protocols, software, data and content for example (Adler-Nissen & Eggeling, 2022; Chander & Sun, 2021; Floridi, 2020; Hummel et al., 2021).

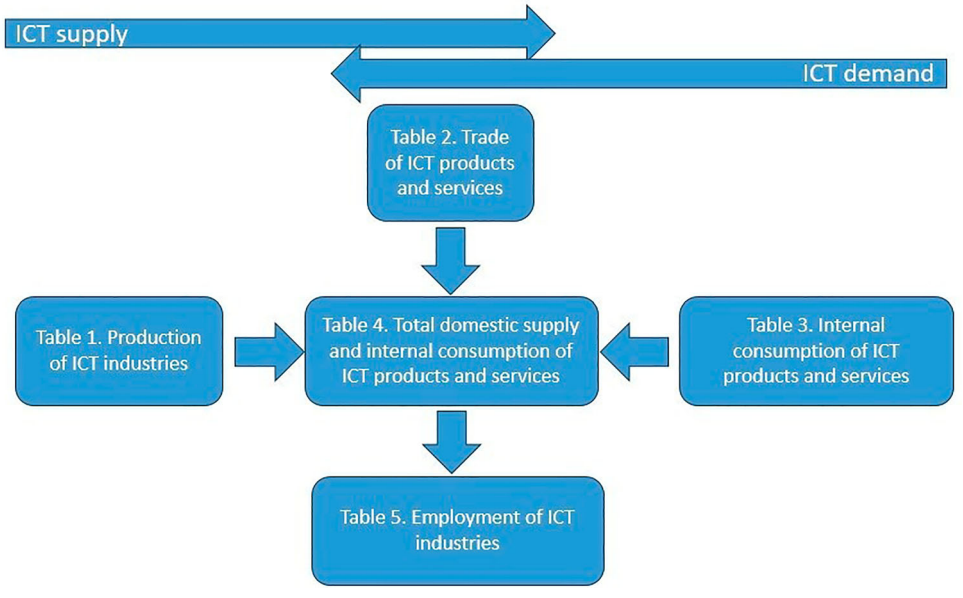
The context above highlights how ICT is an integral and increasingly crucial element of a modern economy. Information technology and computer service activities have their own space in international industry classifications (UN Statistical Directorate, 2024), but also underpin the activities of many (indeed, most) other industries, encompassing many products and services that are crucial to the functioning of the economy and national security. Despite this, there is a lack of tools that enable public authorities at various geographical scales to assess the significance of ICT products and services to the economy, thereby allowing them to better understand digital sovereignty issues.

A corollary is a pressing need for a methodologically coherent and comprehensive way to measure the contributions of ICT products and services to an economy. Satellite accounts have been developed as an adjunct to systems of national or regional accounts (Systems of National Accounts, SNAs) to address information issues of this kind. Satellite accounts 'orbit' SNAs to integrate and reveal the supply and use of hidden specialised products and services of interest, having previously been developed for thematic areas as diverse as tourism, sports, the environment, and the non-market contributions of households (Office of National Statistics, 2018). They are typically framed around input–output tables (IOTs) and Supply and Use tables (SUTs) (see Xu et al., 2020, for further discussion of the role of satellite accounts; Miller and Blair (2022), for an introduction to input–output frameworks; and United Nations Statistics Division, 2018, for additional information). The IOTs and SUTs framework provides a useful means of collating thematic activities that are spread across diverse industries, better accounting for situations where products cannot be easily connected with a defined industry.

In this paper, we show how a developed ICT satellite account can provide insights into the supply and use, particularly of imports and exports of ICT products and services across different industries and products. We also demonstrate how ICT products and services permeate across industries within a nation or region's economy, contributing to a comprehensive understanding of digital sovereignty across all industries. Using the case of Wales in the UK, we can identify the dependency of industries on the outputs of the ICT industry and the opportunities for (and benefits of) import displacement, revealing a series of policy implications from the analysis. More specifically, the developed ICT satellite account framework addresses key factors in the digital sovereignty debate, including dependence on specific ICT industries and the overall significance of the ICT industry to the economy. Figure 1 shows the link between the ICT satellite account tables and SNAs.

Section 2 provides a brief review of the literature on the significance of the ICT industry to the economy and then considers prior research on the development of ICT satellite

Figure 1. The link between the tables of ICT satellite account and SNAs.



accounts, as well as some of the problems encountered in their construction. Section 3 discusses the methods employed in this paper and the sources of data. Section 4 reveals selected results from the account developed. Section 5 explores the policy implications of the analysis, the limitations of the methods and data employed, and concludes.

2. Information and communication technologies in the economy

ICT is defined as activities and products that *'fulfil or enable the function of information processing and communication by electronic means, including transmission and display'* (UN Statistical Directorate, 2024). ICT is not just important for economies at the frontiers of technological development – ICT involvement is evident in every aspect of the contemporary economy (Arushanyan et al., 2014). For example, ICT enables a highly interconnected digital ecosystem (Ting et al., 2020) and works to improve consumer experience (Foroudi et al., 2017). A series of studies have emphasised the importance of ICT products and services in discrete industries, for example, in enhancing agriculture production (Chavula, 2014; Nakasone et al., 2014), and with ICT a key factor driving business growth globally (see, for example, Apiyo & Kiarie, 2018; Billon et al., 2017; Cirera et al., 2016; Grazzi & Jung, 2015). Critical here is the significance of ICT adoption in promoting innovation (Franco & Garcia, 2017; Grazzi & Jung, 2015) and facilitating the application of other technologies (Cirera et al., 2016; Franco & Garcia, 2017).

ICT investment in an economy is thus linked to prosperity. Qu et al. (2017) reveal how ICT investment assists capital deepening and improved labour productivity, while lowering transaction costs, increasing innovation, and consequently improving overall efficiency. Moreover, early work revealed that digital investment is often accompanied by human

capital investment and organizational structural change, meaning that returns to digital investment are often higher than those to physical investment (Jorgenson & Vu, 2007).

While the significance of ICT in driving economic growth and productivity is well established, challenges remain in accounting for differences in ICT activity across different economies and in comparing the role played by ICT across different geographies. Differences in the supply and use side for ICT goods and services might, for example, be a factor explaining productivity differentials between nations.

The importance of ICT industries, explained above, is linked to growing national sensitivities about overseas ownership of these industries, particularly in semiconductors and linked materials, ICT infrastructure, and ICT services. This sensitivity is currently being most explicitly played out in respect of the semiconductor industry. For example, UK Government interest in semiconductors has grown exponentially since COVID-19. The pandemic highlighted the UK's (and that of the US and EU) dependence on complex, distant global supply chains (Huggins et al., 2023). Indeed concerns, such as losing control of a country's own data security, and competitiveness in key technologies of hardware and software production, have been set beside 'digital sovereignty' debates in key ICT technologies, with UK Government interventions in 2022 in the case of the sale of Newport Wafer Fab to Chinese group Nexperia, and concerns about the Nvidia purchase of UK chip designer ARM from Japanese group Softbank.

An issue arising from the above is the need for a better understanding of the role played by different parts of the ICT industry, and more pertinently, how we understand the dependence of parts of the contemporary economy on various parts of this industry. We suggest in this paper that satellite accounting approaches could be useful in improving this understanding. The existing accounts of SNAs do not provide information that accurately reflects the economic impact of ICT industries. Specifically, those accounts do not easily measure the total contributions of the ICT industry as its outputs spread over a wide range of industries in SNAs. Moreover, ICT outputs may be 'hidden' across all industries within the SNAs because of factors such as internal supply. The satellite account approach can reveal the economic importance and nature of functionally related activities that are either outside the scope of national accounts (such as within household economic activity) or hidden inside (and spread across) different industries. While ICT might be manufactured by identifiable ICT firms, its application and development – including for example, maintenance and programming – can be undertaken across a wide range of private and public organisations as noted above. In these circumstances, an ICT satellite account would (ideally) assess the proportion of each industry's commodity output that comprised ICT activities, products or services, and by aggregation, estimate the overall contribution of ICT to total output (United Nations, 2008). Similarly, an ICT satellite account enables some analysis of ICT penetration across different parts of the economy.

Some ICT satellite account frameworks have already been proposed in Germany (Schmalwasser & Greiner, 2007), South Africa (Lehohla, 2015), the USA (Bureau of Economic Analysis, 2023), Australia (Australian Bureau of Statistics, 2021), and by the OECD (Ribarsky, 2018). However, limited progress has been made in ICT satellite account development because of persistent limitations in data availability. For example, details of business purchases of various ICT products and services are rarely available, and data on the employment of internal and external ICT experts within businesses are usually

non-existent. The development of such satellite account frameworks can also be resource intensive. Indeed, the US Bureau of Economic Statistics (BEA)'s Digital Economy Satellite Account was discontinued in 2023 due to budgetary issues (Bureau of Economic Analysis, 2023).

In the development of the Welsh ICT satellite account that follows in the next section, we seek to build upon selected aspects of these initial accounts and reveal the value of an account developed at a subnational level. The main categories of products and services included in the US account were infrastructure and other physical materials to support ICT goods and services, E-commerce, priced digital services, and Federal non-defense digital services that are directly supporting the digital economy. Bridgman et al. (2024) augmented the Digital Economy Satellite Account to include digital services that are supplied by high-tech consumer durables. Consumer durables are treated as a capital asset yielding a service flow over time; imputation is made in the same way as BEA's measurement of owner-occupied housing (market rents are used to account for rents that would have been paid for owner-occupied homes).

In the Wales ICT satellite account, described in the next section of the paper, the purchases of capital goods by households are included in final consumption, as well as fixed capital formation for production by private industries or the public sector. The digital services flow provided by consumer durables in the Wales tables is likely to be included in the ICT services supply and use if the imputation of the digital services flow is considered in the original supply and use data or estimation. There was no additional imputation of the flow of services provided by high-tech consumer durables in our study. BEA's Digital Economy Satellite Account captures the impact of technologies in the US, with a primary focus on global supply chains, providing a more comprehensive view of international trade in ICT products and services. In our study, the Welsh ICT Satellite Account uses a classification of ICT products, services, and industries consistent with OECD (2011). It follows a framework like the well-established Tourism Satellite Account. The focus is on measuring the hidden impact of ICT products and services, such as internal ICT services provided within institutions, which are not reflected in SNAs, and it includes a slightly different range of ICT-related industries. Then, some important differences exist between BEA's Digital Economy Satellite Account, and the Wales ICT Satellite Account described later.

The ICT satellite account compiled by the Australian Bureau of Statistics (2021) has a similar framework to the ICT satellite account suggested in our study, with a supply table to track the supply of ICT products by Australian producers and imports, and a use table to track the use of those products by industries, government, households and exports. However, our developed account differs in two major ways. First, in terms of products and industry classification differences, our study aligns more with OECD classifications, i.e. in the developed Welsh ICT satellite account, the ICT products, services, and industries definition is close to OECD (2011). This then includes a broader range of goods than the Australian definition and is of wider application. Second, in terms of framework differences, the Welsh ICT satellite account mirrors the well-developed tourism satellite account and has a key additional table to reconcile the supply and demand of ICT products and services.

In what follows, we aim to illustrate the value of a regional ICT satellite account with the modifications outlined above. We present this as a set of interconnected tables that reveal

the import, export, production, and consumption of ICT products and services across various industries. Importantly, and as shown above, the methodology employed allows an estimate to be made of the employment and value-added resulting from the consumption of ICT products and services. The method employed also reveals something of the complex inter-dependencies within the ICT industry itself, as well as between the ICT industry and other industries of the regional economy, and with links to international trade dependence. This type of framework helps explain the varying levels of dependence on traded ICT products and services. We reveal the types of information that can be generated from such a satellite account framework to inform policy and show the need for such frameworks to be better developed at different geographical scales to better inform debates about digital sovereignty.

3. Methodology and data sources

We aimed to construct an ICT satellite account that mirrors well-developed national and regional tourism satellite accounts, using comparable standards as applied and explained in United Nations (2008), Frechtling (2010), and Jones and Munday (2010).

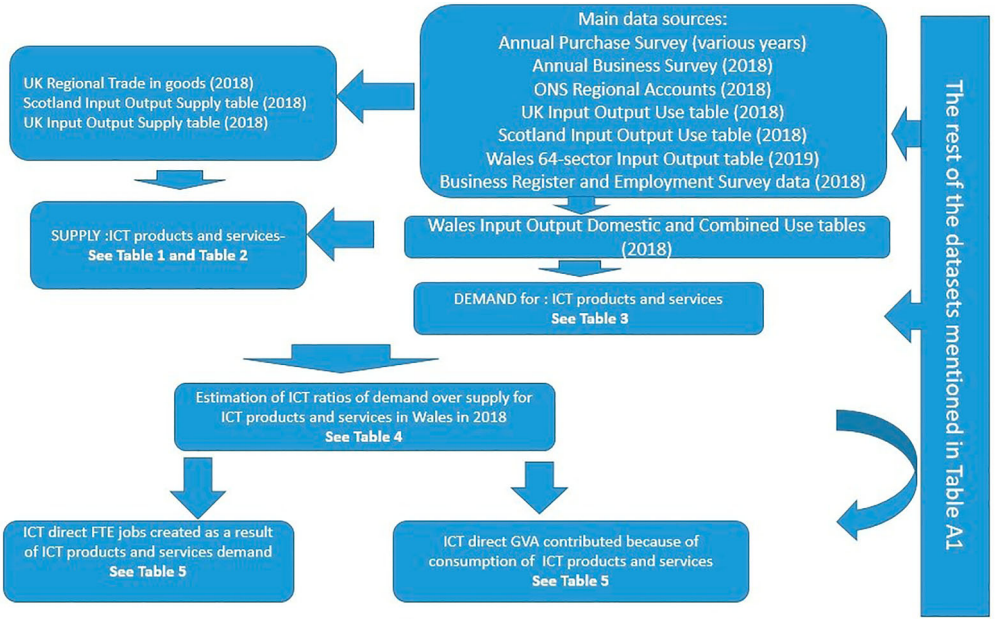
Wales, a devolved administration of the UK, was a valuable lens through which to develop an experimental ICT account. The Welsh Government supported a Superfast Broadband Exploitation Project (2016-2020), and as part of this work, a Digital Maturity Survey was conducted, which collected comprehensive data on the digital economy (Henderson et al., 2020). Most importantly for the development of the ICT satellite account, the Digital Maturity Survey collected data on the number of internal ICT specialists employed within a firm. This information was useful for the estimation of internally supplied ICT services that are not reflected in the SNA.[1] Wales also has a set of strategies on the use of digital technology and its role in improving the lives of people in Wales. The *Digital Strategy for Wales* (Welsh Government, 2021) has objectives focused on developing digital skills in the workforce, promoting digital innovation, and enhancing connectivity. However, the strategy was developed with limited information available on the strength of demand for ICT services in the regional economy, and with little data on the size and scope of the ICT industry. A better understanding of the connections between supply and use of ICT products in Wales may have implications for the skills supply side, which will be important in meeting the aims of such strategies.

In addition to this policy centrality, Wales is a place where satellite account approaches have already been developed for tourism and the environment. In this respect Wales benefits from the presence of an IOT framework (Jones, 2022; Jones & Munday, 2007; Xu et al., 2020). In what follows, we provide an outline of the methodology, with further details in the Appendix. The focus of our paper is more towards the findings. Appendix Table A1 shows the main Office for National Statistics and other datasets used to develop the ICT satellite account. Figure 2 provides a summary of how the data sources were used to develop the account.

The first stage of the project was to build upon the Wales IOTs and SUTs framework to compile Wales input–output use tables for 2018, in both combined use and domestic use

[1] The internal supply of ICT services here was then estimated as the proportion of a firm's output, multiplied by the ratio of service specialists to total staff employed.

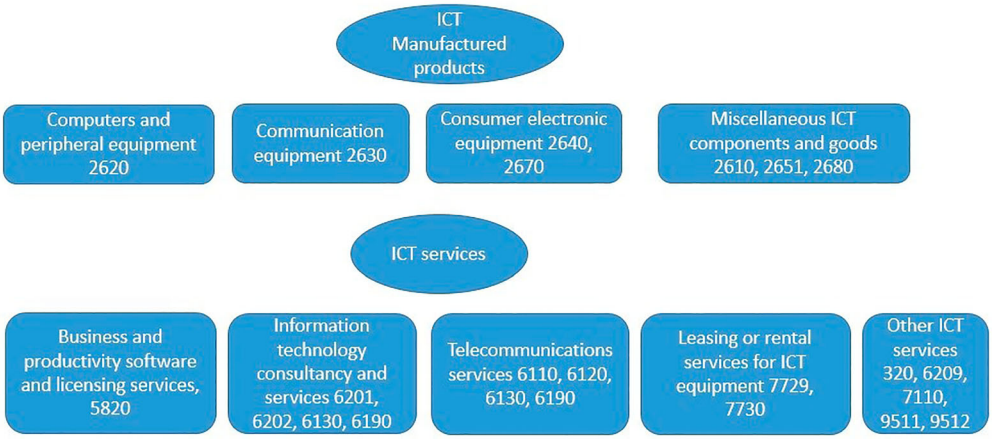
Figure 2. Construction of the ICTSA 2018 for Wales.



form. IOTs show the relationships between inputs (purchases) and outputs (sales) within an economy, revealing the transactions between producers and consumers for distinct products or industries (see Miller & Blair, 2022; United Nations Statistics Division, 2018, for more information on the framework). The flow of products and services includes those purchased for both intermediate use in production and final consumption. A combined use table of Wales' regional SUTs includes imported (here to the region) products and services, whereas the domestic use table of Wales regional SUTs reveals the products and services that are domestically (regionally here) produced. Details on the differences between these two tables and the process by which the combined use table at purchaser's price is derived from the domestic use table at basic prices are provided in Appendix 1 and Figure A1. Both tables were necessary for this study because the total internal use of the products at purchasers' prices is essential for compiling Table 3 of the ICT satellite account. The Wales input–output use tables for 2018 were specifically constructed for the purpose of this study. While they include the usual 2-digit SIC industries, they also incorporate 4-digit SIC ICT-related industries where data allowed. This was done to ensure the fully combined tables could provide as much information as possible for the ICT satellite accounts.

These tables serve as a basis for drawing supply and use information for ICT products and services. More details of constructing the Wales input–output combined and domestic use tables are included in Appendix 1. These tables provide aggregation at the 2-digit SIC industry with additional 4-digit ICT-related industry information where possible. The International Standard Industrial Classification of All Economic Activities (ISIC) defines ICT broadly, differing slightly from the OECD (2011) classification. However, we believe the classifications from OECD (2011) better capture the penetration of ICT products and services across other industries (OECD includes a broader range of activities than ISIC).

Figure 3. ICT products and services classifications by OECD (2011) and corresponding SIC (2007).



We employ official definitions of ICT specialized industries and products from the OECD (2011), but we acknowledge that some of these definitions are contested (see Figure 3).

The development of the ICT satellite account requires the separation and presentation of data on the sales and inputs of discrete ICT industries. Our estimation levered unpublished intelligence from ONS data sources, specifically the Annual Business Survey (ABS) and the Annual Purchases Survey (APS). The former provides information on production functions for industries at the 2- and 4-digit SIC levels, including details on broad purchases, sales/turnover, and gross value-added (GVA) and its components (compensation of employees, other value-added, and taxes less subsidies). Meanwhile, the APS provides information on the purchases of goods and services at the fine industry detail required for the construction of the account. Our estimates provided nuance on whether industry inputs were sourced locally (i.e. in Wales) or imported, with the consequent 'Domestic Use matrix' used in combination with export data to inform regional ICT trade balances.

An iterative process of triangulation ensured our revealed ICT industries were reasonably scaled and structured, both in reference to the remainder of the ICT framework, and to UK IOTs, Scottish IOTs for 2018, and (separately constructed) 64-industry Wales IOTs 2019 (Jones, 2022), as well as the earlier versions of more detailed Wales IOTs. Input–output use tables for Wales in 2018, with detailed ICT industries, were constructed as the first stage of compiling the ICT satellite account. During this process, the main purpose of using UK, Scottish, and earlier versions of Welsh IOTs and SUTs was to further disaggregate ICT-specialized industries, and to further estimate final consumption. One of these additional IOTs or SUTs was typically chosen based on which was more appropriate for the estimation. For example, ratios from SUTs were used for intermediate consumption estimation, while IOTs were chosen for final consumption. The choice between UK, Scottish, or Welsh tables depended on which best reflected the characteristics of the industry or products in question. If the earlier Wales tables lacked certain information, but both the UK and Scottish tables had it available for estimation, the appropriate source was selected based on the closer similarity to the industry or product being analyzed. Further details on estimation processes are provided in Appendix 1.

Table 1. ICT share of GDP and GVA by industry in £m 2018 (combined use at purchaser prices)

ICT industry	SIC	Output	GVA	GVA as % output
Computers and peripheral equipment	2620	58	35	60%
Communication equipment	2630	463	279	60%
Consumer electronic equipment	2640, 2670	169	102	60%
Miscellaneous ICT components and goods	2610, 2651, 2680	815	491	60%
Business/productivity software and licensing services	5820	11	7	64%
Information technology consultancy and services	6201, 6202, 6311, 7020	689	458	66%
Telecommunications services	6110, 6120, 6130, 6190	1,480	1,101	74%
Leasing or rental services for ICT equipment	7729, 7730	65	43	66%
Other ICT services	3320, 6209, 7110, 9511, 9512	406	202	50%
All other industries		129,074	62,506	48%
Total		133,231	65,224	49%

Some construction issues were faced. For example, ICT production, consumption, and trade statistics at a very disaggregated 4-digit SIC level are difficult to find in current national accounts or indeed in any datasets at the national or regional level. Separating them from the existing broader categories, therefore, requires an element of approximation and estimation. The *Digital Economy Survey* (previously E-commerce Survey) has been conducted in the UK since 2015, but without the ICT products and services consumption and supply side information. There are other statistical difficulties. For example, UK inter-regional trade data at the Wales level are not available (Greig et al., 2020). The alternative method for estimation in this study is to estimate based on the relative importance of industries (location quotients) between regions, according to industry employment differences, with the expectation that better data will enable more sophisticated approaches in a fully developed account. Full details on these processes are also provided in Appendix 1.

Our estimation process results in the compilation of the five core Tables;

- The output and GVA of the ICT specialised industries (Table 1)
- Trade in ICT products and services (Table 2).
- The consumption of ICT products across industries and final demand by households and the government (Table 3).
- A reconciliation of products between total supply and internal consumption, providing the key ratios of ICT specialized products and services' consumption over the total supply of all products and services in Wales in 2018 (Table 4).
- The number of Full Time Equivalent (FTE) jobs and GVA created by the production of ICT, and ICT industry productivity (Table 5).

4. The ICT account for Wales

Table 1 shows the ICT industry share of Welsh output and GVA in 2018. Some ICT industries share similarities in their GVA/output percentages due to a combination of data limitations and the methods used for disaggregation. Table 1, however, still shows informative comparisons between ICT industries and other industries. The first thing to note here is the small share of output and GVA contributed by the defined ICT industries in the Welsh case. It accounts for just over 4% of GVA, with *Telecommunications services* being the

Table 2. Trade of ICT products and services by products in £m.

ICT products and services, industries	SIC (2007)	Products export RUK	Products export RoW	Products import RUK	Products import RoW
Computers and peripheral equipment	2620	12.6	34.5	0.6	86.3
Communication equipment	2630	101.9	278.3	5.0	695.1
Consumer electronic equipment	2640, 2670	37.2	101.7	1.8	254.1
Miscellaneous ICT components and goods	2610, 2651, 2680	179.2	489.3	8.8	1,222.3
Business and productivity software and licensing services	5820	0.2	3.9	23.9	9.1
Information technology consultancy and services	6201, 6202, 6311, 7020	234.4	240.7	1,136.6	122.3
Telecommunications services	6110, 6120, 6130, 6190	13.5	75.5	265.0	276.8
Leasing or rental services for ICT equipment	7729, 7730	6.0	12.4	77.5	8.5
Other ICT services	3320, 6209, 7110, 9511, 9512	56.4	67.4	355.0	38.5
All other products and services		11,538.3	14,514.8	68,936.3	14,768.4
Total ICT industries trade as % of all industries trade		5%	8%	3%	16%

primary contributor. Manufacturing elements of the ICT industry (i.e. those under SIC 26) have seen some reductions in activity in recent times as inward investment in these Welsh industries has declined, but with rather stronger levels of activity in semiconductors, with some large inward investors in the Cardiff and Newport areas. GVA as a proportion of output varies slightly between the ICT industries and with this being one indicator of the ability of the ICT industries to make economic contributions within the region (assuming, of course that returns to capital remain in the region), and imports by industry is also an important indicator for measuring regional purchases and digital sovereignty. For the manufacturing elements, the ratio of GVA to output is around 60%, but it grows to 74% in the case of *Telecommunications services*. For all non-ICT industries in Wales, GVA is estimated to be around 48% of the value of output, whereas the ICT industries are characterised by higher levels of GVA in output (the average for ICT industries is closer to 65%). One conclusion from Table 1 is that, for the Welsh case at least, the significance of ICT industries to the functioning of the contemporary economy may not be well reflected in the direct contribution of defined ICT industries to the economy's GVA and output.

Table 2 reveals the trade activity in ICT products and services by the defined ICT industries, showing ICT products and services contributed an estimated 5.2% of Welsh exports to the rest of the UK (i.e. total of ICT products and services divided by total of all products and services exported to RUK), and close to 8.2% of exports overseas. In the latter case, *Miscellaneous ICT components and goods* are an important contributor, accounting for 38% of ICT products and services overseas exports. Semiconductor components are also an important contributor here (see, for example, CSconnected, 2022). Overall, Welsh ICT products and services exports were greater than imports. Importantly, Table 2 reveals the dependence of the case economy on imported ICT goods and services, and the underlying trade balance in these ICT goods and services. Critically, in the Welsh case, imports from the rest of the world tend to be greater than the rest of the world's exports in most of the ICT industries identified. One key value of this type of accounting framework is to highlight areas of trade strength, as well as those industries that are more dependent on imported goods.

Table 3. ICT products and services consumption by industry (excluding export) at purchaser prices in £m.

	ICT industries												
ICT products and services	Computers and peripheral equipment	Comms eqmt.	Consumer electronic equipment	Misc. ICT goods	Business and productivity software and licensing services	Info. technology consultancy and services	Telecom services	Leasing or rental services for ICT equipment	Other ICT services	Total ICT specialized industries	All other industries	Final demand consump.	Total ICT consump.
Computers and peripheral equipment	0.175	0.478	0.515	2.477	0.005	0.446	0.372	0.002	0.214	4.68	17	87	109
Communication equipment	1.408	3.848	4.146	19.950	0.041	3.595	2.993	0.012	1.722	37.72	140	697	875
Consumer electronic equipment	0.515	1.406	1.516	7.292	0.015	1.314	1.094	0.005	0.629	13.79	51	255	320
Miscellaneous ICT components and goods	2.477	6.767	7.292	35.084	0.072	6.323	5.263	0.022	3.029	66.33	247	1226	1539
Business and productivity software and licensing services	0.000	0.000	0.000	0.001	0.002	0.000	0.000	0.008	0.008	0.02	4	45	49
Information technology consultancy and services	0.309	2.674	0.910	4.376	0.471	30.949	14.903	1.768	13.967	70.33	778	481	1330
Telecommunications services	0.076	0.366	0.224	1.078	0.063	10.817	146.772	1.562	7.795	168.75	504	912	1585
Leasing or rental services for ICT equipment	0.006	0.031	0.016	0.078	0.020	0.451	1.508	0.204	0.916	3.23	108	51	162
Other ICT services	0.895	0.993	2.636	12.683	0.064	9.099	2.879	0.141	4.921	34.31	350	140	524
All ICT specialized products and services consumption	5.860	16.562	17.255	83.019	0.754	62.995	175.783	3.723	33.200	399.15	2201	3893	6494
All other products and services	6.397	90.238	18.835	90.620	1.428	140.938	201.488	17.413	292.790	860.15	25018	35636	61514

Table 4. Total domestic supply and internal consumption by products in £m.

ICT products and services	SIC	Domestic supply at basic prices	Imports UK	Imports RoW	Taxes less subsidies on products nationally produced and imported	Domestic Supply (at purchaser prices)	Internal ICT consumption at purchaser prices	ICT Ratios
Computers and peripheral equipment	2620	50	1	86	11	147	109	0.74
Communication equipment	2630	334	5	695	88	1, 122	875	0.78
Consumer electronic equipment	2640, 2670	146	2	254	32	434	320	0.74
Miscellaneous ICT components and goods	2610, 2651, 2680	703	9	1, 222	155	2, 089	1, 539	0.74
Business and productivity software and licensing services	5820	15	24	9	1	49	49	1.00
Information technology consultancy and services	6201, 6202, 6311, 7020	790	1137	122	79	2, 128	1, 330	0.6248
Telecommunications services	6110, 6120, 6130, 6190	1313	265	277	151	2, 006	1, 585	0.79
Leasing or rental services for ICT equipment	7729, 7730	77	78	8	6	170	162	0.96
Other ICT services	3320, 6209, 7110, 9511, 9512	419	355	39	25	837	524	0.63
Other consumption products and services		129, 384	68, 936	14, 768	9, 272	222, 360	12, 074	0.05

Table 5. ICT direct employment and GVA in Wales 2018.

ICT industry	SIC	Full-time	Part-time	FTEs	Employment	ICT ratios	ICT Direct FTEs	ICT Direct Employment	GVA (£m)	ICT Direct GVA (£m)	GVA/FTE (£)
Computers and peripheral equipment	2620	175	75	213	250	0.7367	157	184	35	26	163, 144
Communication equipment	2630	1, 750	45	1, 773	1, 795	0.7798	1, 382	1, 400	279	218	157, 557
Consumer electronic equipment	2640, 2670	625	10	630	635	0.7367	464	468	102	75	162, 029
Miscellaneous ICT components and goods	2610, 2651, 2680	1, 500	140	1, 570	1, 640	0.7367	1, 157	1, 208	491	362	312, 822
Business and productivity software and licensing services	5820	70	5	73	75	0.9978	72	75	7	7	92, 883
Information technology consultancy and services	6201, 6202, 6311, 7020	7, 440	1, 770	8, 325	9, 210	0.6248	5, 201	5, 754	458	286	55, 021
Telecommunications services	6110, 6120, 6130, 6190	6, 575	715	6, 933	7, 290	0.7905	5, 480	5, 763	1, 101	870	158, 817
Leasing or rental services for ICT equipment	7729, 7730	160	550	435	710	0.9572	416	680	43	41	99, 368
Other ICT services	3320, 6209, 7110, 9511, 9512	3, 235	465	3, 468	3, 700	0.6263	2, 172	2, 317	202	126	58, 239
All ICT industries		21, 530	3, 775	23, 418	25, 305	0.7229	16, 928	18, 293	2, 718	2, 011	116, 071
All other industries		801, 970	442, 225	1, 023, 083	1, 244, 195	0.0543	55, 553	67, 560	62, 506	3, 394	61, 096
Total		823, 500	446, 000	1, 046, 500	1, 269, 500	0.0803	72, 482	85, 852	65, 224	5, 405	62, 326

There has been a long-standing interest in Wales in improving levels of local sourcing of goods and services and promoting intra-regional trading. It is expected that trade linkages create knowledge spillovers between industries. Table 3 provides some details on the extent to which ICT products and services are used by different industries (and households). Note that this approach accounts for the fact that products listed in the rows might not necessarily be all produced by the 'diagonal' main industry (this is particularly important in terms of some ICT services). Moreover, reading across the table reveals the industry's use of different ICT products and services, totalling the domestic intermediate demand for these ICT products and services. For example, in the case of *Computer and peripheral equipment* products, around £4.7 million is used by ICT-specialised industries in Wales, while £17 million is used by non-ICT industries in Wales, and £87 million is used by Welsh households. Table 3 also reveals that total regional demand for ICT products and services in 2018 was estimated at around £6.5 billion, or approximately 10% of the demand for all products and services.

Table 3 also highlights the varying dependencies of Welsh industries on ICT products and services (reading down the columns). For example, the *Computer and peripheral products* industry uses an estimated 47.8% (total ICT products and services consumption divided by total products and services consumption in the industry) of ICT products and services, as opposed to other products and services. In the case of *Communication equipment*, this percentage falls to around 16%. Table 3 also reveals the extent to which ICT industries purchase products and services 'close' to their activity area. For example, the *Communication equipment* industry purchases £3.8 m of communication equipment products and services. Table 3 then identifies some of the supply chain interdependencies between different parts of the ICT industry, as well as connections between the ICT industry and wider industries in the economy. These intra-ICT trading linkages are important to understand, given the significance of the ICT to economic prospects outlined in Section 2.

The final column of Table 3 is also important, as it reveals the total regional demand for selected ICT products and services, although some of these same products and services are also produced by non-ICT industries in Wales.

Table 4 then brings together elements of the supply and use of ICT products and services, estimating the domestic (here, regional) supply of each industry alongside the domestic demand for ICT products. In the case of *Computers and peripheral equipment*, the total domestic output of the industry is estimated at £147 million, but total industry and consumer demand for Computers and peripheral equipment products at £109 million. Then, around 74% (termed the ICT ratio) of the output of *Computers and peripheral equipment* in the region is linked to ICT products and services expenditure, and with 26% of industry output attributable to the production of other products and services not linked to ICT. ICT ratios are shown in Table 4 to be quite variable. For example, for ICT equipment, close to 96% of domestic regional output is connected to demand for leasing or rental services for ICT equipment products. Here, then, much of the industry output can be connected to ICT spending.

The developed ICT ratios are useful as they allow (with some assumptions) estimates to be made of how much of the regional GVA and employment is connected to the demand for ICT products and services. Importantly, this approach allows us to consider that industries other than those conventionally considered as ICT industries have activities that are linked to ICT spending in the regional economy.

Table 5 provides estimates of ICT industry employment and GVA and then uses the developed ICT ratios to reveal the amount of activity linked to spending on ICT products and services. Table 5 also provides useful descriptive information on the ICT industry in Wales, for example, revealing the relationship between full-time and part-time employment in the different industries, and the productivity difference in terms of GVA per FTE between the ICT industries.

Table 5 reveals that ICT industries in Wales in 2018 employed around 25,300 people, equating to 23,400 full-time equivalent employees. By applying the developed ICT ratios to each defined industry, it is possible to account for employment in each industry supported by ICT product and service consumption spending. Of the total 23,400 FTE employees in the ICT specialised industries, around 16,900 are supported by spending on ICT products and services. However, Table 5 also reveals an ICT ratio of around 5% in respect of all other Welsh industries, meaning that consumption spending on ICT products and services supports close to 55,000 FTEs in non-ICT industries in the Welsh economy. In total, then, consumption spending on ICT products and services is estimated to support over 72,400 FTEs (i.e. around 6.9% of total Welsh FTE employment).

Similar principles are used to derive estimates of the Welsh GVA connected to the consumption of ICT products and services. For example, in *Computers and peripheral equipment*, total industry GVA in 2018 is estimated as £35 million, but only £26 million is linked to ICT products and services. The remainder of the GVA is linked to other products and services of the industry.

Finally, Table 5 suggests differences between ICT industries in terms of GVA per FTE employee. One point of interest here is that, in most cases, productivity in the ICT industries is well above the Welsh average, and this is particularly true in manufacturing, partly reflecting high levels of capital intensity in industries such as compound semiconductors and general communications equipment. This characteristic has been identified in other studies (see CSconnected, 2022).

5. Conclusions

The context for our paper was to better account for the activity of the ICT industry in an economy and to better understand the intra-linkages within the industry in terms of trade, but also the use of ICT products and services across a broader range of industries. The developed framework considers issues of industry and regional dependence. Such interconnections are important given the centrality of the ICT to the economy. We also revealed that a better understanding of the contribution of the ICT industry and how its outputs serve as inputs for other key industries in an economy is important. These perspectives are particularly important considering the increasing scrutiny of overseas ownership of strategic ICT industries and the importance of understanding how the growth or decline of ICT industries may impact other parts of the economy.

We acknowledge that this pilot work is being undertaken at the level of a devolved region, rather than a national economy. However, the point we make is that these accounting structures may be important for informing and contextualizing strategies that are being put in place to support (or indeed to protect) elements of the ICT industry. We argue it is difficult to examine issues of digital sovereignty and dependence in the absence of this type of accounting, which goes beyond comparative trade advantages in different ICT product

and service groups. This type of satellite accounting might usefully inform the further development of national and more local interventions around industries such as semiconductors. This is because the framework identifies elements of the value chain together with information that describes the economic characteristics of the industry in terms of employment and GVA.

More generally, our approach allowed for the measurement of the overall contribution of ICT in a manner consistent with SNAs. This means that the overall impact of ICT across the case economy could be measured and compared with other established industries.

The results reported here mark an early attempt to develop an ICT satellite account for any part of the UK economy, and one of the few that exist globally. This type of development is much overdue. Selected ICT industries are becoming more important in the contemporary economy. At the UK level, there have been growing concerns about the supply side of ICT industries, particularly those linked to semiconductors, telecommunications, and other electronic components, which are also linked to national security considerations (Friis & Lysne, 2021; Kaska et al., 2019). However, aside from this understanding, the scale and scope of the ICT industry is vital for other reasons. For example, the developed account reveals the high productivity evident in selected ICT industries, such that variations in the regional supply side of these activities might be associated with regional productivity differentials. As importantly, the paper reveals something of how ICT products and services are created by non-ICT industries, often supporting a core activity. This element of the developed account is interesting as it reveals more of the actual regional supply side in ICT; a simple focus on the main 'ICT' industries hides this perspective.

The ICT satellite account is a valuable tool for consolidating information on the demand and supply sides of the industry from diverse sources. We believe this is critical for developing local and national policy and potential interventions in ICT industries. A good example here is policy interventions that seek to improve levels of local purchasing, such that policymakers can better examine where there are supply side gaps. With growing policy interest in strengthening the regional and UK value chain in ICT, the additional insight provided by such an account is particularly useful. The account is also relevant context for interventions seeking to improve the ICT skills base. Moreover, in economic strategies developed by policymakers, ICT activities are often bundled together, but with a poor understanding of the differences in terms of who purchases which ICT products, the interdependencies between different parts of the ICT industry, the varying levels of productivity and employment in discrete parts, and the links to the broader economy.

A further challenge in the development of ICT satellite accounts, particularly in the context of the problems outlined in the introduction to this paper regarding foreign involvement in key ICT industries, is to develop perspectives on how production and employment in ICT firms are controlled by overseas as opposed to domestically owned firms. Work in this respect has occurred around tourism satellite accounts (Xu et al., 2019). An ICT satellite account that distinguishes between external and regional ownership could mirror the framework of Tourism Satellite Accounts in Xu et al. (2019), where the regional and external supply of ICT products and services was separated. However, the challenge would be to estimate the regional and external demand for ICT services and products, which would require additional investigation and primary business surveys.

While we believe there is value in our framework, much remains to be done. There is a clear need to update the current set of tables to reflect the post-COVID-19 period, given the

changes in digital technology use that occurred during the pandemic. Unfortunately, the survey data at the time of writing is not available to undertake this update. There are also two main challenges in compiling and applying the ICT satellite tables. Firstly, the methodological approach and data collection process (see Appendix) reveal that the development has been data-intensive, requiring intelligence to be gleaned from an extensive range of sources. Additional surveys that collect detailed information on firm and household ICT use and report on firms' internal ICT services supply may be needed. Moreover, although the research has been carried out utilising the best available methods and data resources, approximations and assumptions were required throughout the process. In addition to the data currently missing, existing data often lack the necessary level of detail, which drives some differences between our framework and OECD approaches. Consequently, the second main challenge in developing an ICT satellite account is promoting consistency and comparability across regions and countries. This may be extremely difficult, as, unlike the Tourism Satellite Account, there is currently no widely recognized framework for ICT satellite accounts. Furthermore, various data limitations and inconsistencies in statistical standards across different locations make such comparisons even more challenging.

Therefore, while more refined surveys of national or regional consumption and trade statistics may help, specialized surveys on the digital economy are likely to be one of the most important improvements for developing and compiling a higher-quality ICT satellite account. The general framework of an ICT satellite account is still at its early stages of development worldwide. This paper has contributed to identifying data deficiencies that may be remedied, conceptual issues that require further exploration, and comparability issues. A widely recognized and well-defined ICT framework recommendation, along with statistical guidance from international institutions such as the United Nations Statistics Division, would be very helpful in promoting the application and comparability of such frameworks globally.

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Appendix 1. Methods and Construction

The figure below summarizes the structure of Wales input–output use table 2018, and how the combined used tables could be transferred into the domestic use tables.

Following the standards set by the United Nations Statistics Division (2018), the domestic use matrix at basic prices was the first step in the construction of Supply and Use Tables (SUTs) and Input–Output Tables (IOTs). Accordingly, the standard SUTs, which include intermediate consumption at basic prices, were constructed first. However, the total internal use of ICT products at purchaser's prices is essential for constructing the ICT satellite account. The ICT ratio—defined as the ratio of total internal consumption at purchaser's prices to total supply at purchaser's prices—is a core element of the ICT satellite account framework developed in this paper. This framework mirrors the well-established Tourism Satellite Account framework (United Nations, 2008).

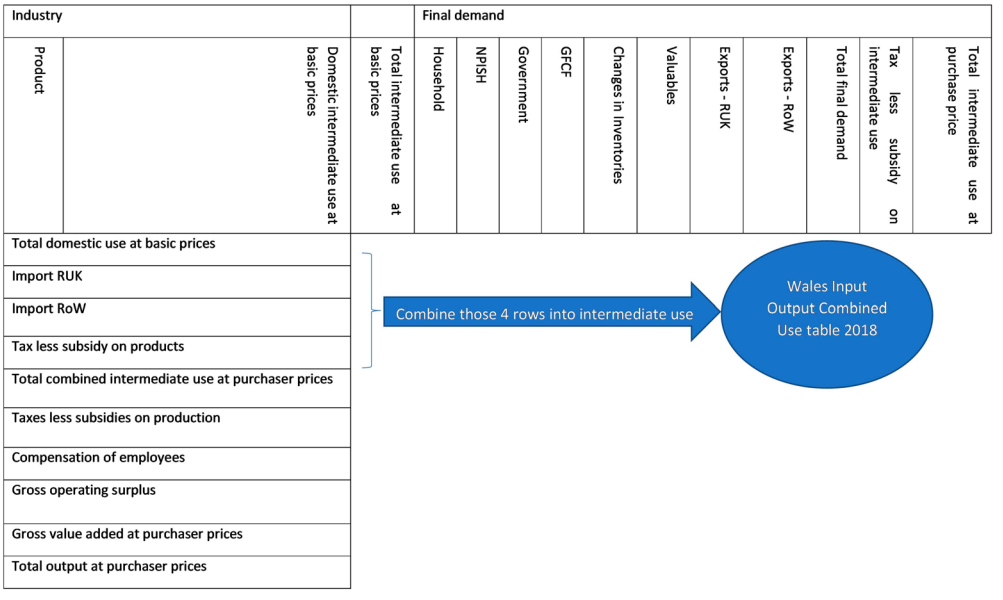
To support this process, the Wales Combined Use Table 2018 was created as an additional SUT based on the domestic use table. This allowed for the direct extraction of total internal intermediate consumption at purchaser's prices and final consumption at purchaser's prices.

As illustrated in Figure A1, in addition to the standard SUTs and IOTs, the combined use table incorporates total domestic use, imports, and taxes and subsidies on products. This approach enables the estimation of the total combined intermediate use at purchaser's prices for each industry. These values are then allocated across products using use ratios derived from the standard use table (i.e. use ratios at basic prices). Adding total combined intermediate use at purchaser's prices and final demand as well as tax less subsidies on the domestic intermediate use at basic prices would provide the total internal use of products at purchaser's prices.

Through this method, the total internal combined use by product at purchaser's prices can be accurately estimated. Table A1 below summarises the main data sources employed in the analysis of this paper.

The Annual Business Survey (ABS) was used to gain estimates of industry total turnover, GVA, and output. Industry (column totals) were estimated at 2-digit Standard Industry Classification

Figure A1. Wales combined use table 2018 methodology.



(SIC 2007) in the first instance. Additional 4 digit SIC ICT related industry categories were added where needed in accordance with the OECD ICT products and services guide (OECD Publishing, 2011). 4 digital total outputs are either available in ABS or estimated proportionally according to employment.

Data on the purchase details of goods and services (allowing the estimation of total intermediate consumption by industry) was available from the Annual Purchase Survey (APS). Purchase ratios were drawn from the APS for total intermediate consumption allocation. Data on sectoral GVA were from ONS Regional accounts. The components of GVA (providing breakdowns of primary inputs by industry at 2 digits SIC) were drawn from 3 resources, ABS, UK IOTs and Scottish IOTs. When data in the ABS did not match with any publicly available information, Scottish or UK IOT ratios of GVA components were applied.

Output for own final consumption, including Household expenditure, Non-Profit Institutions Serving Households (NPISH) Final consumption expenditure, Gross fixed capital formation, Imports of products, Importers' trading margin, Taxes less subsidies on products, change in inventory were estimated from the Wales IOTs for 2019.

Construction of domestic use table

Total combined use of each industry was apportioned to domestic use, imports, taxes less subsidies on products, according to ratios of imports to GVA or output in the Scotland and UK supply and use tables, adjusted by the relative importance of each industry in the region, mainly according to sectoral employment differences between within and outside of the region when compared with Scotland or UK tables for 2018.

Construction steps for each table of ICTSA

ICTSA Table 1

Industry output and GVA were estimated using the combined use or domestic use table column totals. Those totals are available at the most granular industry level possible according to ONS SRS

Table A1. Office of national statistics and other datasets employed in ICTSA development.

Main data source (ONS Secure Data Service)	Purpose of use or intended use
SN 7451 Annual Business Survey	Estimation of industrial GVA and output in Wales. Breakdown of GVA components.
SN 8558 Annual Purchases Survey	Industry purchase information for Welsh industries.
SN 6729 UK Manufacturers' Sales by Product Survey (PRODCOM)	The estimation of manufacturing products produced by industry. Value and volume include not only the production by businesses classified to the SIC industry where it is primarily produced but also its subsidiary production by enterprises classified to other SIC groups.
SN 6690 Business Enterprise Research and Development	Wales supply of R&D.
SN 6697 Business Structure Database	Estimation of total supply by standard industrial codes (SIC codes) in Wales.
SN6700 E-commerce Survey	ICT related establishments of businesses in Wales.
SN 6711 International Trade in Services	Used to gain an estimate of Welsh service exports to the rest of the world in terms of industries defined in the Welsh IOTs.
SN 7047 Living Costs and Food Survey (Expenditure and Food Survey)	Estimation of final household demand for each industry's products and services.
SN 7882 Quarterly Acquisitions and Disposals of Capital Assets Survey	Specific ICT products/services such as hardware, software programs, databases, telecommunication equipment are surveyed such that it provides further useful information on demand for ICT products/services by businesses.
Other publicly available data sources	**Purpose**
ONS regional accounts	Estimates of GVA by Welsh industries.
UK Supply and Use Tables 2018	GVA and output ratios
Scotland Supply and Use Tables 2018	Purchase ratio, intraregional trade, products, and industry output ratio
Wales Input–Output table 2019	Final demand estimations
Business Register and Employment Survey data	2 and 4 digits SIC employment, details of how they are used are included in ICTSA Table 1 constructing steps.
Other data sources that are available to the team	**Purpose**
Digital Maturity Survey	Estimates of Welsh firm's internal supply of ICT services with information on internal ICT experts employed and other appropriate estimates.
Earlier version of Wales IOTs	More detailed final demand estimations if such information is not available from other datasets, as earlier Welsh IOTs have more detailed industry classifications.

data following clearance rules, combined with published data and data available to authors' research institution, following all the data protection procedures. However, most of the 4-digit SIC industry totals or purchase ratios for Wales in 2018 were not available for this analysis due to minimum secure data publication clearance requirements and fundamental data scarcity.

For those industries that required more details (typically at the 4-digit SIC level) then employment from the ONS Business Register and Employment Survey (BRES) was used to apportion output, GVA and industry purchases from the 2 digit to 4 digit SIC industry level. The following formula takes output for an example and illustrates how the apportion was done:

$$4\ digit\ SIC\ industry\ Output = 2\ digit\ SIC\ industry\ output * \frac{4\ digit\ SIC\ industry\ employment}{2\ digit\ SIC\ industry\ employment}$$

ICTSA Table 2

Products trade, including export to and import from the UK and the Rest of the World (RoW), was drawn from Wales input–output domestic use tables for 2018. If the product or industry category was not in the 4-digit SIC format that the ICTSA industry classifications required, then the trade totals were apportioned according to employment from the ONS Business Register and Employment Survey in a similar way as shown in the Table 1 formula. GVA and output were estimated for each 4-digit or 2-digit SIC industry.

ICTSA Table 3

Industry's combined consumption (excluding export by products, including imports from UK and RoW, and taxes less subsidies on products by industry). The Annual Purchases Survey is the main source for purchase or consumption information for 2-digit and 4-digit industries in Wales in 2018. The PRODCOM data is used to estimate which industries supply certain products or services. The underlying assumption in the construction was that most industries are dominated by their main products as opposed to by-products. The purchases of certain ICT products (in 4-digit product format) were derived from PRODCOM with better detail than was available for the APS. When there was differences between information drawn from PRODCOM and APS, APS is preferred because its purchase information include both services and products. The use of the purchase ratios from APS to allocate the totals would be more reliable because all possible purchases are surveyed in APS, whereas PRODCOM only provides detailed supplies for manufacturing products. Products supply ratios from PRODCOM are sometimes preferred when certain 4-digit ICT products purchase information was not available in APS.

When the consumption or purchase information for the 4-digit ICT products and services was not available from either APS or PRODCOM, employment from the ONS Business Register and Employment Survey by 4-digit SIC in Wales 2018 was used as a basis for apportioning the 2-digit industry and products consumption of ICT products and services, or any other consumption products and services into 4-digit industries as required. The underlying assumption is that consumption patterns between the different 4-digit ICT specialized companies under the same 2 digit SIC are the same.

ICTSA Table 4

Total domestic supply at purchaser price including domestic total supply at basic prices, imports UK, imports RoW, and tax less subsidies on products by industry. Total domestic supply categories information was drawn from corresponding column totals in the Welsh domestic use table 2018. This was apportioned according to employment from BRES and developed in a similar way as described in prior tables.

Total domestic supply at purchaser price is the total supply of all the products and services. Total internal supply by industry would be a sum of the domestic supply, imports from UK, imports from RoW, tax less subsidies on products. Total internal consumption of the industry on the ICT specialized products and services by ICT specialized industry and all other industries are calculated following from ICTSA Table 3. This means that a reconciliation of total internal supply and use results in ICT ratios which are critical for ICTSA Table 5.

ICTSA Table 5

Employment in this table includes VAT or Pay-As-You-Earn (PAYE) schemes registered self-employed workers and working owners, self-employed not registered for these and HM Forces and Government Supported trainees are excluded. Employment including full-time, part-time employees, employment (employees plus work owners) is drawn from the ONS Business Register and Employment Survey.