Valuation for the accounting of free digital services[*]

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Abstract

The goal of this paper is to provide a road map for the compilation of a set of aggregates that incorporates the value of free digital services. First we discuss how the value of free digital services can be measured using methodologies developed for environmental accounting. We then employ one of these strategies to measure the value of three forms of free digital products for the UK: videoconferencing, personal email, and online news. Lastly, we explain how these estimates can be incorporated into an accounting framework, which describes the production process and how the value of digital services is generated. For the empirical part of the paper, we find that the aggregate gross value derived by households from the consumption of the three forms of digital services was between £7 billion and £25.4 billion in 2020. This is around 0.6 to 2.1 percent of the UK's household final consumption or 0.3 to 1.2 percent of the UK's GDP in the same year. This is comparable to the share of communication services to total consumption.

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1 Introduction

There is a growing literature that suggests that the significance of the digital economy cannot be fully captured by macroeconomic measures such as GDP and Household Final Consumption. For instance, if companies like Google or Microsoft decided to stop offering free email services or if Meta withdrew free access to WhatsApp, how much would these decisions affect consumers? How much trade would be lost if Facebook and Instagram are no longer available for online sellers? These questions cannot be answered by official statistics.

While we can assess the relative importance of traditional market goods by examining their share in total consumption, such an approach is limited for digital services. This is because the National Accounts framework only considers goods and services with market prices[1], leaving out the contribution of products that have no explicit cost to households. This includes many services offered through the internet such as social media, personal email, and search engines, among others. Therefore, it is difficult to examine the impact of the digital economy on overall economic activity using existing data.

The goal of this paper is to provide a road map for compilation of a set of aggregates that incorporates the value of free digital services. First we discuss how the value of free digital services can be measured using methodologies developed for environmental accounting. We also employ some of these strategies to measure the value of three forms of free digital products: videoconferencing, personal email, and online news. Lastly, we explain how these estimates can be incorporated in an accounting framework, which describes the production process and how value of digital services is generated.

For the empirical part of the paper, we employ the prices of "premium" or paid internet goods as proxy for the value from their free counterparts. For instance, we use the price of paid versions of Zoom as a source of valuation for its free version. We use hedonic regression in order to isolate the value free component from these goods from the value of the premium-exclusive component. Hedonic regression is an econometric approach wherein the price of a good is expressed as a function of its characteristics[2], with the goal of estimating

[1]With some exceptions such as government services, imputed rent from owner-occupied dwellings, the extraction of ground water from wells, among others.

[2]In this context, characteristics are features that describe the good. For cellphones, they can be RAM, storage space, camera quality, etc.

the price, or willingness to pay for the characteristics included in the specification. Our estimates show the aggregate gross value derived by households from the consumption of the three forms of digital services was between £7 billion and £25.4 billion. This is around 0.6 to 2.1 percent of the UK's household final consumption. This is comparable to the share of expenditure communication services to total consumption. This tells us of how important free digital products are to UK households.

This paper contributes to the growing literature on the measurement free digital services. As of writing, there is no consensus on how to measure the value of free digital services Corrigan et al. (2018), Brynjolfsson et al. (2019b,a), Coyle (2015) and Jamison and Wang (2021) used stated preference to elicit the value of certain types of free digital services from their respondents. Meanwhile, Soloveichik (2015), Nakamura and Soloveichik (2015), Nakamura et al. (2017), Van Elp and Mushkudiani (2019), and Van Elp et al. (2022) used advertising and marketing expenditures to represent the value derived by households from these services.

If the goal is to examine the contribution of free digital services to overall economic activity, then the estimated value of these products should be comparable to other measures of production and consumption. We will discuss later how results from stated preference studies can be used as a starting point for the valuation of these activities. However, further work should be done to ensure comparability with measures of production and consumption in the National Accounts. While using the cost of production for measuring non-market activity is fully consistent with National Accounts practice, the approach is limited in termsof measuring welfare changes if the marginal cost of producing each unit of the product is close to zero, which is the case of many internet services.

This paper extends the literature in three ways. First, we discuss how the value of free digital services can be estimated in a way that is consistent with the accounting principles of the System of National Accounts. We do so by using the price of goods from similar markets. A common measurement strategy for estimation of non-market goods. To our knowledge, we are the first to use this approach in the context of free digital products.

Second, we develop an accounting framework that describes how production takes place, as well as the inputs required for the production of digital services. In our framework, we create a distinction between the value received by households from the consumption of free digital services from the value of viewership. We argue that while viewership can be represented by advertising and marketing expenditures, the value to consumers of the digital services themselves can exceed the value of viewership.

Lastly, we outline some of the steps required for the construction of a set of statistics describing the relationship between internet services and the digital economy. This includes possible measurement strategies to estimate the value of other forms of free digital products. We also discuss some of the data requirements for the full implementation of the accounting framework that incorporate the value of free digital services.

The outline of this paper is as follows. In the next section we discuss how other non-market accounts, particularly the environmental satellite accounts, measures non-market activity. We employ one of these methods in section 3 to arrive at estimate for the value of select digital products in the UK. We propose a framework for the accounting of the value of these services in section 4 and we explain the data and methodological requirements for the full implementation of the framework in section 5. Lastly, we end with some concluding remarks.

2 Valuation for non-market activities

Measuring the value of goods and services without a market—and consequently, outside the production boundary of the National Accounts—is not a new endeavour. A number of non-market activities, such as government services and services from owner-occupied housing–are currently included in standard GDP estimates. Moreover, some satellite accounts focus on extending the production boundary of the SNA to include non-market activities. In this section, we focus on the valuation methods employed by a particular type of non-market account: the environmental satellite account. We then draw parallels with some aspects in the digital economy, highlighting how methods for the valuation of ecosystem services can be used for the valuation of free digital services.

Since the release of the seminal paper by Leontief (1970), many economists and statisticians have expressed interest in measuring the contribution of the environment to overall economic activity. These efforts eventually led to the development of the System of Environmental Economic Accounting (SEEA), a statistical framework designed to produce a set of aggregates describing environmental assets and flows and their relation to the market economy.

A key feature feature of the SEEA is its consistency with the accounting principles of the core SNA framework. The framework stresses that valuation of environmental assets and ecosystem activities should follow the same valuation principles employed for other assets and activities in the National Accounts. The rationale for this is to allow for comparability with other macroeconomic aggregates. The SEEA Ecosystem Accounting manual writes:

> In ecosystem accounting, the primary motivation for monetary valuation using a common monetary unit or numeraire is to be able to make comparisons of different ecosystem services and ecosystem assets that are consistent with standard measures of products and assets as recorded in the national accounts. This requires the use of exchange values. In turn, this facilitates the description of an integrated system of prices and quantities for the economy and the environment that is a core motivation of the SEEA Ecosystem Accounting. (SEEA Ecosystem Accounting, par 8.2)

Maintaining consistency with the SNA provides the advantage of having a benchmark for analysis. This adds to the usefulness of aggregates generated using the SEEA framework.

2.1 Valuation for ecosystem accounting

The SEEA Ecosystem Accounting manual recommends a range of techniques that can be employed for the estimation of the monetary value of these flows. These methods include: the use of prices from similar markets, residual value approach, productivity change method, hedonic regression, replacement cost method, travel cost method, avoided damage cost method, and simulated exchange value method (see United Nations (2014), Markandya et al. (2022)). We will not discuss the details of each approach in this paper. However, our goal is to discuss the context in which some of these valuation methods are employed and reflect on their possible applications for the measurement of the digital economy.

SEEA dismiss the role of contingent valuation and stated preference in providing a sound valuation methodology for environmental accounting. It argues that these approaches would incorporate consumer surplus into the estimated value of ecosystem services. Since it is the intention of environmental accounting to maintain consistency with the valuation principle of the National Accounts, SEEA suggests any valuation techniques that may incorporate consumer surplus to the value of ecosystem services should not be considered without appropriate adjustments and a validation.

In a report commissioned by the World Bank, Atkinson and Obst (2017) discusses three channels in which ecosystem services benefit households. They argue, that choice of valuation techniques should depend on these channels. In this section, we describe these three channels, provide some examples, and enumerate the recommended valuation method for each of the channels.

ES#1: As input to production. Here, we can think of ecosystem services as intermediate inputs to the production of market goods and services. For this channel, it is assumed that the value of ecosystem services is embedded in the value of market goods. For instance, natural pollination is required for some agricultural activities. The goal of valuation, in this case, is identifying the contribution of ecosystem inputs to the value of market goods.

Recommended valuation methods: Production function approach, change in productivity.

ES#2: As substitute or a complement for the market goods. Here, ecosystem services can be inferred from related market goods, which can either be a substitute or a complement. For instance, the value of the ecosystem services provided by the beach is complementary to travel expenses. For this example, the idea is that market goods are combined with ecosystem services to produce another product. Another example is when market goods can substitute for ecosystem services. For instance, the value of flood control systems can be used to partially infer the value of mangroves (or at least the flood prevention function of mangroves). For this channel, revealed preferences approaches—such as hedonic regression and travel cost approach—are used for valuation.

Recommended valuation methods: Price of similar products, travel cost method, hedonic regression.

ES#3: As a direct contributor to household utility. Here, ecosystem services are directly consumed by the household. The value of ecosystem services is distinct from market activity.

Recommended valuation methods: Stated preferences, contingent valuation, simulated exchange value.

While the SEEA is cautious about the use of stated preferences for the valuation of ecosystem services, Markandya et al. (2022) noted that these methods can be used as a starting point for constructing estimates close to exchange value. They argue that demand curves can be estimated using stated preferences, which is the initial step for simulating a market for ecosystem services.

The main point of Markandya et al. (2022) is that context matters for valuation. They argue that the way ecosystem services should be valued depends on the three channels listed above.

2.2 Parallels with the digital economy

In this section, we discuss how the taxonomy provided by Markandya et al. (2022) can be used in the context of the digital economy. One can find parallels to the challenge faced by ecosystem accounting to those encountered by economists attempting to measure to the value of free digital services. First, the goal of both measurement exercises is to develop a set of methodologies, which can provide a shadow price for non-market activities. Second, maintaining consistency with the valuation principles of the SNA will add to the usefulness of the estimates. Users of the data would be able to compare the value of activities from the digital economy with other activities from the broader market economy.

As with ecosystem services, one can argue free digital services can also benefit households through the three channels defined by Markandya et al. (2022) and so measured in a similar way. In table 1, we outline the different channels in which free digital services can have an impact on households. we also provide some examples and possible methods for the estimation of the monetary value of the service.

As with ecosystem services, free digital products can also benefit households as inputs to production (ES#1). Productivity tools such as Google Docs and Google Sheets are being used by many professionals in their daily work activities. Taxi drivers have started using Google Maps to allow them to get to their destinations much faster. For this channel, we can assume that the value of digital services in embedded in the price of market goods and the role of valuation to estimate the contribution of these services to the total value of the market product.

The value of free digital products can also be inferred from the value of related market goods (ES#2). This is more apparent for the case of substitutes. we will discuss this in detail in the following section.

Table 1

Channels	Examples	Possible valuation methods
ES#1 As inputs to production.	Googles maps as an input to transportation services like Taxis, Google Scholar for researchers, Google Docs, Google Sheets for many industries.	Production function; change in productivity
ES#2: As substitute or a complement for the market goods.	Amazon as a trading platform, ride-hailing apps such as Uber, food deliver apps, and online banking, free versions of goods with premium services.	Market substitutes, hedonic regression
ES#3: As a direct contributor to household utility.	Online maps, social media, streaming sites.	Stated preferences and simulated exchange value method

Lastly, some digital services are distinct from the value of market products (ES#3). Social media is a prime example. It is difficult to think of any market product that functions similarly to platforms such as Facebook or Twitter. We can say the same for other forms of digital services such as search engines, review websites (Yelp, etc), and online maps. Since these services are detached from market transactions, this makes the estimation exercise more challenging. As such, perhaps the best way to arrive at the value of these flows would be ask households directly how much they value these flows through stated preferences or contingent valuation surveys and experiments. Results from stated preferences estimate demand curves that can be used to arrive at simulated exchange value. Though this would also involve making some assumption on the institutional arrangement for the provision of the digital service.

A challenging aspect for free digital services, however, is that some services can cut across channels. In particular, many products that provide utility directly to households (ES#2 and ES#3) can also be used in the production of market goods (ES#1). For instance, while Google Docs is often used for work, the service can also be used for keeping personal notes. Google maps can be used by Taxi drivers, but it can also be used by tourists and commuters. This makes it a bit challenging in terms of identifying the proper valuation method for certain products. As such, stated preference studies which aims to estimate the value of free digital services should take this into consideration in the design of their measurement instrument. It must be clear to the respondents that the goal of the survey (or experiment) is to elicit the value they derive from the *personal* use of these service. Measuring the value of free digital services used in the production of market goods should be a separate endeavour. For such exercise, time use surveys can be employed to estimate the working hours spent using free digital services.

In the next section, we discuss in detail how valuation can be applied in the context of measuring the value of free digital service flows using channel (ES#2). We also present estimates for three type of free digital service, which videoconferencing, personal email, and online news.

3 Valuation for free digital services

In this section, we measure the value for a set of digital services, videoconferencing, personal email, and online news. In the previous section, we mentioned that the measurement strategy for free digital services should depend on the type of products being measured. In this context, we argue that these services are related to some market goods (ES#2). Therefore, we can infer the value of these services to related products.

As our measurement strategy, we employ the prices of "premium" or paid internet services as proxy for the value from their free counterparts. For instance, we use the price of paid versions of Zoom as a source of valuation for its free version. This strategy is a common practice in non-market valuation. The SNA suggests the use of prices of products from similar markets as a source of valuation for non-market goods when prices cannot be observed. Paragraph 3.123 of the 2008 SNA states:

> When market prices for transactions are not observable, valuation according to market-price-equivalents provides an approximation to market prices. In such cases, market prices of the same or similar items when such prices exist will provide a good basis for applying the principle of market prices. Generally, market prices should be taken from the markets where the same or similar items are traded currently in sufficient numbers and in similar circumstances. If there is no appropriate market in which a particular good or service is

> currently traded, the valuation of a transaction involving that good or service may be derived from the market prices of similar goods and services by making adjustments for quality and other differences. (see United Nations and others (2009))

Compilers of National Accounts statistics often use market substitutes to impute the value of certain non-market goods, such as services from owner-occupied housing, barter transactions, extraction of groundwater, and agricultural products for own consumption, among others. Compilers of the Household Satellite Accounts also use this strategy to value household services such as childcare. The use of prices from similar markets is also the strategy endorsed by the European Commission for the valuation of ecosystem services for environmental accounting (see European Commission (2016))

We assume that information on the value of free digital services is embedded in the value of its paid version. However, subscribers to premium services would have access to the services provided by the free version with the addition of other features exclusive to the premium version. One can argue that the price of the premium versions p_p would have two (2) components: a 'freely-available' p_f and a premium component p_z. If the relationship of the two components are additive, the price of premium services can be expressed as,

$$\underbrace{p_p}_{\text{price of premium service}} = \underbrace{p_f}_{\text{`freely-available' component}} + \underbrace{p_z}_{\text{premium-exclusive component}} . \tag{1}$$

The component 'free component' can be interpreted in two ways. From the producer's perspective, the free component would represent the cost of producing services that is also available for free, if one chooses to consume it separate from the bundle of premium-exclusive services. This begs the question of why producers would supply these free components. One possibility is that the price charged to premium users subsidises the free component. However this is unlikely as premium users represent less than 1 percent of their total number of user[3]. A more likely explanation is that producers want to capture those who are prepared to pay premium rates and provide the free component to drag them in. From the perspective of consumers, this represents the value derived by

[3]For Zoom, only 470,100 of their 200 millions users are subscribed to their paid service in 2020: https://www.businessofapps.com/data/zoom-statistics/

households from the consumption of the services that it can also acquire through the free version of that good.

The challenge is to isolate the prices attributable only to the services present in the free versions. We employ hedonic regression to disentangle the price attributable to free services from the price of their premium versions. This strategy effectively limits the scope of our estimation to goods having paid counterparts. As such, we also use hedonic regression in order to extract the value free component from these goods and untangle them from the value of the premium-exclusive component. Hedonic regression is an econometric approach wherein the price of a good is expressed as a function of its characteristics[4], with the goal of estimating the price, or willingness to pay for the characteristics included in the specification.

To estimate the shadow price of free digital services, we acquired data on the price of the paid versions of digital services, as well as information on premium-exclusive characteristics from different service providers (Zoom, Cisco Webex, Microsoft Teams, etc.). We fit a semi-log regression, which includes service provider fixed-effects and no constant term. As such, each of the fixed effect can be interpreted as the quality-adjusted prices for each service provider. Lastly, we generated estimates of the prices, setting the value of the premium-exclusive characteristics to zero, and taking the average of the fixed effect. We use the confidence interval of the regression coefficients to generate upper and lower bounds of the price estimates.

To arrive at estimate of the gross value of free digital goods, we multiply the estimated prices to the number of users of each service. We discuss the detailed methodology in appendix 1.

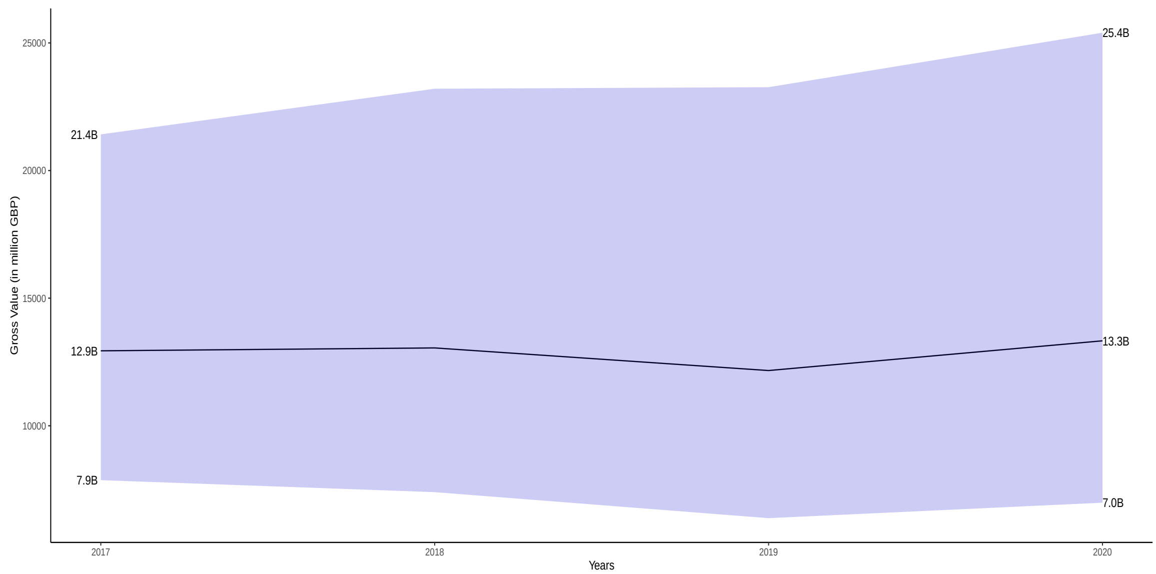
3.1 The value of free digital services in the UK

We interpret our estimates as measures of the gross value of free digital goods. As such, we consider our estimates as part of the consumption side of GDP rather than the production side. The current price estimates of the gross value of digital goods are shown in figure 1. The initial figures that we generated were in USD. In order to be comparable with the UK's National Accounts data, we convert the estimates to GBP. We apply only one

[4] In this context, characteristics are features that describe the good. For cellphones, they can be RAM, storage space, camera quality, etc.

exchange rate (which is the average exchange rate from 2017 to 2020), in order to avoid having foreign exchange fluctuations affect our results.

Figure 1: Gross value of digital goods accounting for multiple service provider usage, at current prices



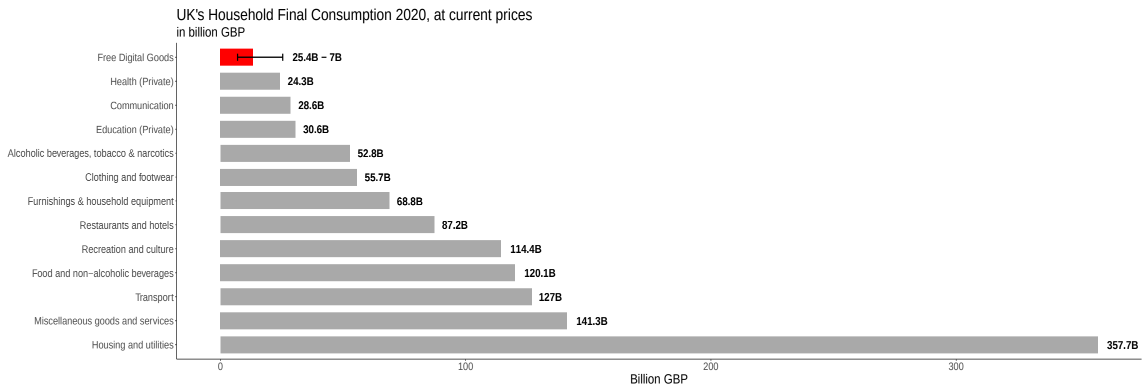
Note: The table shows the interval estimate of the aggregate gross value (at current prices) for the three digital goods, videoconferencing, personal email, and online news, accounting for multiple service provider use.

Our estimates show that the gross value of digital goods is around £12.9 billion in 2020. The interval estimates show that the the gross value of free digital goods is between £7.0 billion to £25.4 billion in 2020 (see figure 1). Based on our results, free digital goods account for 0.6 to 2.1 percent of the UK's HFCE in 2020 and 0.3 to 1.2 percent of the UK's GDP in the same year.

The figures that we generated, however, are likely conservative estimates of the true value of free digital goods for two reasons. First, we are unable to account for multiple service provider use for email. It is possible that many internet users hold multiple accounts from different free email providers. Second, we only accounted for the users of the top three videoconferencing providers. Due to data constraints, our estimates do not include users of Facetime, WeChat, Skype, and even Zoom. Both of these reasons are likely to cause our estimates to have a downward bias.

Despite this, we argue that our estimates for the value of free digital goods is economically significant. For context, the lower limit of our estimates is already 30 percent of the total final consumption expenditures for communications, which is at £28.6 billion (see figure 2). Meanwhile, the upper limit almost exceeds the value of the same expenditure item.

Figure 2: Comparison with other expenditure items



Note: The figure compares the current price estimates of gross value of free digital goods (accounting for multiple provider use) with other expenditure items under UK's HFCE for 2020. HFCE data is sourced from the ONS.

We also generate constant price estimates by deflating the nominal figures with an implicit Laspeyres price index. We chose 2019 as the reference year in order to be consistent with the ONS. We add the constant price estimates to the chain volume measure estimates of the UK's HFCE and GDP to generate "expanded HFCE" and "expanded GDP" measures that includes the consumption of the three digital products. We show the growth rates in table 2.

Table 2: Growth rates of digital goods and household consumption for multiple service provider usage, at constant prices

	2017-2018	2018-2019	2019-2020
HFCE	2.08	0.99	-12.94
GDP	1.71	1.6	-11.03
Digital goods			
Point Estimate	1.53	2.32	1.64
Lower	1.67	2.22	1.95
Upper	1.43	2.39	1.46
HFCE + digital goods			
Point Estimate	2.08	1.00	-12.82
Lower	2.08	1.00	-12.88
Upper	2.07	1.01	-12.71
GDP + digital goods			
Point Estimate	1.7	1.6	-10.96
Lower	1.7	1.6	-10.99
Upper	1.7	1.6	-10.90

Note: The table shows the the growth rates of the household final consumption expenditure and gross domestic product chain volume measure estimates estimates of the ONS, constant price estimates of the gross value of digital goods, HFCE + digital goods, and GDP + digital goods. Figures are in percent.

Our estimates show that the impact on real HFCE decline in 2020 was between 0.06 to 0.23 percentage points. For GDP, the impact to real GDP decline in 2020 was between 0.04 to 0.13 percentage points. This suggests that welfare, as measured by aggregate consumption, would have been worse had it not for the presence of these free goods. While these impacts are relatively small, it is important to note that we are measuring the value of only three categories of internet services for this exercise. The inclusion of other internet services could have a substantial impact on the household consumption statistics and GDP.

In the next section, we discuss how we can construct a framework for the accounting of free digital services.

4 Accounting for free digital service flows

Measuring the value of free digital goods is a starting point. It is necessary however, to think about how these estimates would fit a broader description of the relationship between the digital economy and household welfare. In order to do this, we need to organize an accounting framework that includes the flows of free digital services.

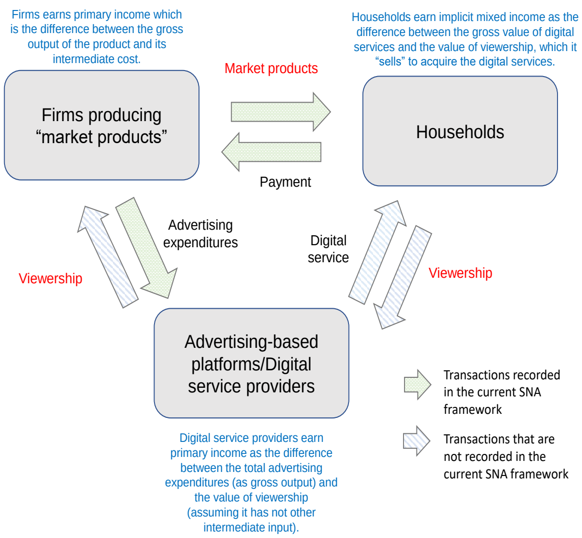
For the accounting of the value from the production and consumption of free digital services, it is important to understand how value is created. What type of inputs are combined to produce these services? Who are the agents involved in the transaction? The literature provides two possible answers to these questions. Schreyer (2021) argues that "leisure services" are generated through the own-account production of households by combining time and ICT capital. Meanwhile, a series of papers including those by Soloveichik (2015), Nakamura and Soloveichik (2015), and Nakamura et al. (2017) (from here on, we will refer to this string of papers as the barter approach) argued that the provision of free digital services is a product of a barter transaction between households and advertisers/marketers. Households *produce* viewership, which it *sells* to advertisers and marketers, who, in exchange, provide content to households.

Schreyer (2021) argues that digital service production can be characterized as household production for own use. This is similar to when agricultural households produce food for their own consumption. In this paradigm, it is the household that earns labour income (or mixed income) from the production process. One limitation of this framework, however, is that digital service providers (say, Meta and Google) and firms spending on advertising are noticeably absent in the setup. Meanwhile, the barter approach recognizes the service providers in the ecosystem. However, it assumes that the value of the service is equivalent to the value of viewership.

In this paper, we argue that while digital services are a product of a barter transaction between service providers and households, we can also imagine that the value of these services to be above the value of viewership that households are selling in exchange for the service. We illustrate these transactions in figure 3.

For conventional products, firms sell goods and services to households. In return, households provide a monetary payment for the goods that they enjoy. The difference between the intermediate cost of these goods (electricity, materials, etc) would form part of the firm's primary income. Primary income can take the form of either wages (income of workers) or operating surplus (returns to the entrepreneur), assuming that the firm does not employ capital and does not pay taxes.

Figure 3: Transaction flows of free digital services



Note: The diagram shows in an economy where households consume free digital services. The green arrows represent flows that are within the current production boundary of the SNA. The blue arrows represent transactions that are outside the current production boundary. This simplified model of the economy assumes that digital service providers do not employ intermediate inputs.

For the case of free digital services, we can imagine households as producers of viewership. The households sell viewership to advertisers, which in turn provides digital services as *payment* for the viewership. We can think of viewership as a form of intermediate cost, the household has to pay in order to gain digital services. The difference between the value of digital services and the value of household viewership is its implicit primary income gained from the consumption of free digital services. This will take the form of mixed income, the term the SNA employs to describe income that cannot be distinguished from labour income and income from the entrepreneur. The transactions in this framework is similar to the barter approach by Nakamura et al. (2017). The key difference is that we allow the value of free digital services to exceed the value of viewership. As such, the household earns a surplus, which we can think of as the value added of free digital services. This framework requires little conceptual changes to the SNA.

From the discussion above, we present two key takeaways. First, the consumption of advertising and marketing-financed digital services results in the production of two outputs: the digital services themselves and viewership that households and firms need to sell in a barter transaction in order to gain access to these digital services. This was the argument of Nakamura et al. (2017) and the previous versions of their paper. However, we argue that the value of these digital services and the value of viewership does not need to be equal. We can think of the value of free digital services as gross output and viewership as intermediate consumption. This leads us to the second key takeaway, which is that households gain implicit income above the value of their viewership. The platform does not gain anything from the production of digital services, aside from the margin from trading viewership from household to the firm. Rather, it is households that gain *income in kind* from selling their viewership in exchange for digital services. It is as if the household is a few dollars richer by selling its viewership to gain access to Google Maps. This income is represented by the service it received from the platform. This is similar to the framework put forward by Schreyer (2021), where he argues that households earn a form of labour income from the production of the own-account production of free digital services.

The intermediate inputs of households does not have to be limited to viewership. It can be extended to anything that requires the presence of households in the digital ecosystem. As such, we can also think of household data as intermediate inputs as well as their inclusion in a platform's network for the generation of network effects. However, complications would arise with these extensions since data and network inclusion can also be categorised as capital inputs rather than intermediate inputs. As such, it would be important to determine the lifespan of these inputs.

We noted earlier in this section that consistency with the SNA's accounting framework is critical in order for estimates to have a wider range of practical applications. As such, all estimates should be valued based on exchange value. The value of viewership can be represented by advertising and marketing expenditures. In essence, the goal of these expenditure items is for firms to acquire viewership or *attention* to their products. This is consistent with exchange value since they can be considered as the value placed by firms on viewership.

We illustrate the accounting of free digital services through a simplified supply and use table employing the principles from the framework above. Without the loss of generality, we consider an economy with three industries, each producing one output: 1) The oil industry, 2) the advertising industry, and 3) the soap industry. The output of the oil industry is used as an intermediate input of the soap industry. The soap industry, meanwhile sells its output directly to households for final use. The soap industry also spends on advertising in order to promote its product. The advertising expenditures is used to produce entertainment content (say, free streaming services such as Youtube) that households enjoy while intermittently displaying advertising material to the viewers.

In the conventional National Accounts framework, expenditures in advertising would be recorded in the use table as part of intermediate consumption. In our simplified example, only the gross value of soap is recorded as part of final demand. While advertisers produce content that directly feeds into the household's utility, this is not reflected in the use table. Instead, the value of advertising is embedded in the value of the soap. The problem with this approach is that we are not able to directly examine the value derived by households from the consumption of content streaming.

Figure 4: Proposed approach

	Oil Industry	Advertising Industry	Soap Industry	Household Digital Service	Household Viewership	Intermediate Demand	**Final Demand**	**Total Use**		
Oil			10			10		**10**		
Advertising			10			10		**10**		
Soap						0	**50**	**50**		
Household Digital Service							**25**	**25**		
Household Viewership				10		10		**10**		
Intermediate Consumption	0	0	20	10	0	30			**GDP**	**Total Use**
Value Added	**10**	**10**	**30**	**15**	**10**				**75**	105
Total Output	**10**	**10**	**50**	**25**	**10**					
						GDE	**75**		-	
						Total Output	105			

Note: The diagram shows the use table employing the proposed approach.

The solution proposed by Nakamura et al. (2017) and earlier versions of their paper is to record advertising expenditures as part of final consumption rather than intermediate consumption. To execute this approach, a new industry is created, which is household viewership. The approach imagines households as a producer of viewership, which it sells to advertisers in exchange for free digital services, which in this case is a streaming services. Here, we see that GDP is higher as compared to the conventional accounting approach since final demand is augmented by advertising expenditures.

Our proposal extends this approach by allowing the value of digital services and the value of viewership to differ. We illustrate the use table in figure 4. For simplicity, we record household production of digital services and household production of viewership as separate industries (though in practice, they can be recorded as one industry producing two commodities, as reflected in the supply table). The value of the final product soap remains the same. The value of the final consumption of digital services is higher than the value of advertising expenditures and higher than the value of viewership. The difference between the value of digital services and the value of viewership is recorded as implicit primary income (or value added) *earned* by the household sector from producing digital services for own use.

In the next section, we discuss some of the ways to move forward with the generation of a satellite account that include free digital services. We discuss the data requirements of such satellite account and possible extensions.

5 Ways forward

In section 3.1, we demonstrate how we can estimate the value of three types of digital products: videoconferencing, personal email, and online news. In order to implement the accounting framework we discussed in the previous section, however, we also require information on the inputs household employ for the own-account production of these services. We discuss these inputs in this section as well as other considerations for the compilation of a satellite account that incorporates the value of free digital services.

5.1 Household inputs

We note that the value of inputs by households is essential for describing the production process of free digital service flows. This may take the form of viewership, the personal data that households sell, or even the value of the network effects generated from the user's inclusion to the platform's ecosystem. The estimation of these inputs may be even more challenging than the estimation of the gross value of the service themselves. However, we argue that this is a necessary step in order to isolate the value from themselves from the value of the attention provided by the households to advertisers.

Most of the free versions of personal email and online (i.e. Gmail, Yahoo Mail, CNN) operate as advertising-supported services. As such, the inputs employed by households for production in this case is viewership. To estimate the value of viewership, researchers can employ the advertising revenues earned by each service provider. This method assumes that advertising expenditures represent the willingness to pay of advertisers to gain access to viewership. This is similar to the approach of Nakamura et al. (2017), where they employ the cost of producing advertising-supported media as a proxy for the value of free media. In our case, however, we interpret advertising expenditures as the value of viewership. We argue that the value of the free digital products themselves exceed the value of viewership.

For videoconferencing, the estimation of the value of inputs can be more complicated. Most of these platforms operate on a freemium business model. The goal of platform owners is to offer a free version to some users hoping that a even small percent of its users would avail of the premium version. These types of platforms largely rely on network effects. For instance, after the pandemic, many business users prefer to use Zoom because Zoom's user base has expanded significantly at that time. By joining the network, a free user actually improves the ability of Zoom to entice more premium users since the company can boast a large user-base as its selling point.

Measuring the value of household inputs from the consumption of free services by platforms such Zoom requires the measurement of these network effects. How much does an individual user contribute to the value of the network? This could be estimated using econoemetric methods by incorporating the number of users into the hedonic regression specification. This approach assumes that the value of the network effects is embedded in the price of the paid version of the service. Platforms with high user base can charge more as compared to platforms with smaller user base.

We do not present estimates for the household inputs at this point. We aim to do so moving forward.

5.2 Valuation of other digital products

We earlier demonstrated the feasibility of estimating the value of free digital services, if prices for similar market products can be found. This approach has various applications as many free services provided by the internet would have a paid counterpart. These include services such as storage (Dropbox, OneDrive, Google One), office tools (Google Docs, LaTeX), dating apps, and online games. However, not all free digital services fall under this category.

There appears to be a strong interest in measuring the value of digital services that directly contributes to household welfare. For many of these activities, it is difficult to identify paid counterparts that can be used as a basis for valuation. For instance, while

Youtube currently has a paid version (Youtube premium), there are only few paid alternatives to Youtube. As such, we lack the cross sectional variation needed to estimate a hedonic regression equation, which would allow us to separate the value of the premium-exclusive component from the free component. Twitter has started to roll out a paid subscription services (Twitter Blue) and there are news reports are citing that Facebook is planning a similar strategy. However, similar to Youtube, there is only one provider. As such, we cannot use hedonic regression to differentiate the price of free service from the price of premium-exclusive component.

For this category of services, it may be necessary to employ stated preference methods for the estimation of the value for these flows. As with ecosystems measurement, we can employ stated preferences for products that are distinct from market activities (ES#3). There have been many studies that applied stated preferences for various forms of digital services. This include the studies by Corrigan et al. (2018), Brynjolfsson et al. (2019a), Nguyen and Coyle (2020), and Jamison and Wang (2021). These studies involve surveys that aim to elicit the respondents willingness to accept for certain digital services, or the amount users need to be compensated to abstain from using certain types of digital products. They do this so by asking a version of the question:

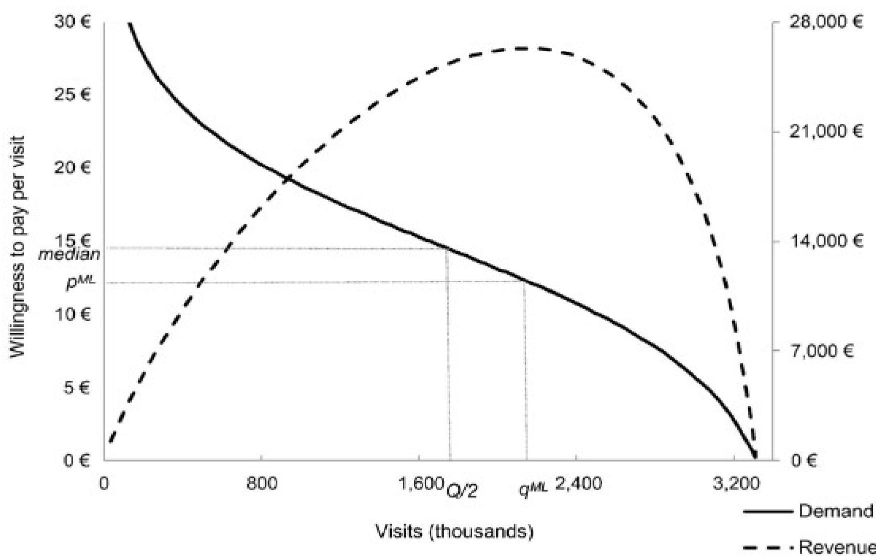
'How much are you willing to be paid to give up Facebook for a month?"

They use either the median or mean WTA as the proxy for the price of these digital services. Perhaps alternative to using WTA, is to use willingness to pay (WTP). This is the amount of money users are willing to give up in order to gain access to certain products. A possible way to elicit WTP is by asking survey respondents:

"If Meta, the company that owns and operate Facebook, plans to discontinue offering the social networking site for free, what is the acceptable monthly subscription price that you are willing to pay in order to gain access to Facebook as it is now?"

While WTP is not exactly equivalent to exchange value, it can be a starting point for the generation of simulated exchange values. This approach requires information from a demand curve (which can be generated from a stated preference study) and some assumptions on the supply curve to estimate the exchange value of goods and services. Caparrós et al. (2017) demonstrates the use of this approach for the estimation of ecosystem services for certain leisure parks in Italy (see. table 5). The approach was also recommended by Markandya et al. (2022) and SEEA Ecosystems Accounting manual (see United Nations (2014)) for the estimation of the value of ecosystem service flows.

Figure 5: Simulated exchange value for recreational service by ecosystems in Cazorla



Note: The figure shows the SEV estimates Caparrós et al. (2017) for select nature sites in Cazorla, Italy.

Since surveys and online experiments are expensive endeavours, the use of stated preferences can be limited to digital products that are distinct from market activities. As such, their value cannot be inferred from other market activities. However, this provides a powerful tool for measuring the value of free digital services.

Future work in this field should also examine the contribution of free digital services to the production of market goods and services. There is little work in this area. As we discuss in section 2.2, one possible measurement strategy would be to estimate a production function, which incorporates free digital products as part of inputs. For this endeavor, we imagine that time-use surveys could be used to provide indicators of how much workers spend using free digital services in their work routine.

While there is not much research on this, the linkages between free digital service providers and producers of market goods is very relevant in terms of describing how the internet is shaping human society. It answers the question, to what extent are these businesses vulnerable to shocks in the provision of these services?

6 Summary and conclusion

Clearly, more work is needed to arrive at a set of statistics for the monetary value of free digital services. In this paper, we show how the value of some parts of these services can be measured using existing available data. We also describe a possible framework for the accounting of these flows and the data requirements.

From the valuation example that we presented, we find that while the value of the three forms of digital services is small relative to the UK's GDP, the estimates are comparable to many of the consumption items that are important to the average household. This is despite the fact that we've only accounted for three forms of digital service. A set of estimates might reveal a more important role of free internet products to overall welfare.

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Appendix

1 A primer for measuring free digital products

A.1 Measuring prices

The Lancaster (1966) model suggests that households derive utility from "characteristics" rather than the goods per se. For instance, individuals do not consume houses, but the characteristics associated with houses such as their ability to shield from the elements, security from other people, the overall aesthetics of the structure, to name a few. Hedonic regression applies this principle by allowing for the estimation of how characteristics are able to contribute to the value of goods (see Groshen et al. (2017)). This method has been used to generate quality-adjusted price indexes (see Triplett (2006), de Haan and Diewert (2013), Groshen et al. (2017)) and the estimation of the willingness to pay for producing particular characteristics of goods (see de Haan and Diewert (2013)).

For this research, we employ hedononic regression to estimate the implicit price of free digital goods using prices of their "premium service" counterparts. In particular, we limit the scope of this exercise to videoconferencing services, personal email, and online news. We assume that premium versions of these goods are imperfect substitutes of the free versions. As such, the price of premium versions would reflect the willingness to pay for the utility derived from the consumption of the services. In this case, the price of the paid version of free digital goods would reflect the marginal utility from these goods as a characteristic, which is also present in their free version. However, we cannot simply use the market price of premium services as a proxy for free services because the former also incorporates the marginal value attached to characteristics that are present in premium versions but are not present in free versions. For instance, Zoom and Microsoft Teams allow for the creation of breakout rooms in their premium versions but not in the free versions of their services. Their prices reflect this and employing these prices to impute for the value of free goods would yield biased estimates. Hedonic regression allows us to control for these characteristics and estimate the price of these services once premium-exclusive characteristics are removed.

The hedonic regression approach assumes that the price p_i of a good i can be expressed as a function of its characteristics z_{in} and a random error term ε_i. Thus, We have,

$$p_p = f(z_{i1}, ..., z_{i,n}, \varepsilon_i) \quad \text{(A.1)}$$

for a good with n characteristics. The marginal contribution of each characteristic can be estimated through a regression framework. In this study, we employ the logarithmic-linear (or semi-log) model[5]. In this exercise, we employ a modified time dummy variable model given by:

$$log(p^t_{i,j}) = \sum_{j=1}^{J}\sum_{t=1}^{T}(\delta_j \times \tau^t) + \sum_{k=1}^{K}\beta_k Z_{i,j} + \varepsilon_{i,j} \quad \text{(A.2)}$$

where $log(p^t_{ij})$ represents the the natural log of the prices at year t. The index i indicates the plan type (Standard, Pro, Business, etc) while the index j represents the service provider (Zoom, Cisco Webex, Microsoft Teams, etc). The list of service providers and their respective pages are listed in the appendix. These prices are regressed against a set of characteristics contained in matrix Z_{ij} and a set of service provider fixed effects δ_j. Details on the characteristics are described in section **??**. In our specification, the term $(\delta_j \times \tau^t)$ represents the interaction term between the service provider dummies δ_j and year dummies τ^t. This ultimately generates separate intercept terms for each service provider for each year. We interpret each of the intercept terms as the quality-adjusted price for each service provider j for time t. The error term ε_{ij} is assumed to be normally distributed with mean 0 and constant variance. For this paper, we follow the technical guidance of Aizcorbe (2014) and those of de Haan and Diewert (2013). One of the difficulties in implementing the hedonic approach is its sensitivity to the regression specification. It is critical that all characteristics that determine the price should be included as explanatory variables, otherwise this would lead to omitted variable bias. We incorporate all features advertised on the service providers' websites that are not multicollinear with the service provider fixed effects.

In a typical regression framework[6], the intercept term a_0 represents the expected value

[5] An alternative is the linear specification where the levels of prices are used as the dependent variable. Diewert (2003) noted that it is more appropriate to employ the log-linear model for technological goods since it often mitigates the problem of heteroskedasticity as their prices tend to have a log-normally distribution.

[6] Consider a typical regression equation $y_i = a_0 + \sum_{k=1}^{K}\beta_k X_i + \varepsilon_i$ where outcome y_i is expressed as a linear function explanatory variables contained in matrix X_i

of the dependent variable if the value of all explanatory variables are zero. In the context of this research, the said parameter represents the average (log) price of free goods if the value of all premium-exclusive characteristics is netted out. As such, $exp(a_0)$ would reflect the shadow price of the free version of digital goods. In the context of this research, since we allow each service provider to have a different intercept for each point in time, our hedonic regression equation would produce separate quality-adjusted price indices for each service provider. To impute the price of free digital, we take the average of these quality-adjusted price indices for the specific year (see table A.3). For videoconferencing and email, we also include continuous variables as regressors that cannot be assumed to be zero. These are the number of participants in the case of videoconferencing and the mail storage in the case of email. We assume a certain value for these variables (z_1) in the prediction model and multiply them by their coefficient. Lastly, the expectation of the error term $E(log(\varepsilon_{ij}))$ should be taken into consideration in the estimation of the price, otherwise, the estimates would be biased. The standard correction suggested by the literature (see Pakes (2003); Aizcorbe (2014); Erickson (2016)) the inclusion of the term $exp(0.5Var(\varepsilon_{ij}))$ for a log-linear model. The imputed price of free videoconferencing can be calculated by the expression:

$$\hat{p}^t = \left[\frac{1}{J} \sum_{j=1}^{J} exp(\delta_j^t) \times exp(\beta_1 log(z_1)) \right] \times exp(0.5Var(\varepsilon_{ij})) \tag{A.3}$$

In the area of official statistics, this approach has been adopted to generate quality-adjusted price indices for technological products by the US Bureau of Economic Analysis (see Groshen et al. (2017)) and the UK's Office of National Statistics (see Bean (2016)).

One limitation of our approach is that we were only able to control for characteristics that were stated on the service providers' websites. It is possible that other characteristics–such as speed, size of the subscriber network, and aesthetics of the interface, to name a few–would affect prices but are not explicitly indicated as a feature of the service as stated in their websites. Moreover, traits like the subscriber network are often undisclosed. The aesthetics of the interface is also difficult to quantify. We try to address this by incorporating service-provider fixed effects δ_j, which are intended to control for these differences. It is assumed that characteristics such as those mentioned earlier are specific to the providers of the service and their marginal contribution to prices should be absorbed by dummy variables.

A.2 Measuring Gross Value

To estimate the aggregate willingness to pay for free digital services, we multiply its imputed price from equation A.3 by a volume measure. The total monetary value of free goods V^t can be expressed as,

$$V^t = \sum_{f=1}^{F} \hat{p}_f q_f^t \tag{A.4}$$

where p_f is the shadow price[7] of free digital good f and q_f^t is a measure of its volume (or quantity). The expression V^t would represent the aggregate value derived by individuals from the consumption of free internet goods and could be part of household final consumption. This begs the question, what is the most appropriate measure of volume for our purposes?

There are two ways one can think about volume when it comes to digital services 1) the number of times an individual accesses a specific service (every time a person opens or uses the application), and 2) simply having access to the service (subscription). The first is more intuitive. It assumes that utility is derived from the direct consumption of the good (i.e. when a person eats at a restaurant). The second, one assumes that utility is derived simply by having access to the service, whether they use it or not. An example of this is a gym membership.

[7] The price we generated from the hedonic regression was based on monthly subscriptions. To arrive at the annual price, we multiply the imputed monthly price by 12.

Figure 6

TABLE 5: INTERNET ACTIVITIES, 2007 TO 2020

Within the last 3 months %

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Sending/receiving emails	57	62	68	69	:	73	75	75	75	79	82	84	86	85
Finding information about goods or services	58	59	59	58	62	67	66	73	70	76	71	77	78	81
Internet banking	30	35	41	42	44	47	50	53	55	60	63	69	73	76
Using instant messaging services (eg Skype or WhatsApp)	:	:	:	:	:	:	:	: :		:	:	:	72	71
Social networking (eg Facebook or Twitter)	:	:	:	:	45	48	53	54	57	63	66	65	68	70
Reading online news, newspapers or magazines	20	34	39	39	42	47	55	55	61	60	64	:	66	70
Watching video content from sharing services such as YouTube	:	:	:	:	:	:	:	: :		47	:	62	:	66
Listening to or downloading music	:	:	:	:	:	:	:	: :		:	:	:	:	62
Looking for health-related information (eg injury, disease, nutrition, improving health e	18	24	32	30	34	:	43	:	48	51	53	54	63	60
Watching internet streamed live or catch-up TV	:	:	:	:	:	:	:	: :		43	:	56	:	59
Watching Video on Demand from commercial services	:	:	:	:	:	:	:	: :		29	:	46	:	56
Making video or voice calls over the internet (eg via Skype or Facetime)	8	:	16	18	17	32	25	:	36	43	46	45	50	49
Playing or downloading games	:	:	:	:	:	:	:	: :		32	:	31	:	41
Selling goods or services over the internet	12	13	14	16	25	22	28	23	21	18	19	25	29	21
Making an appointment with a medical practitioner via a website or app	:	:	:	:	:	10	:	10 :		15	:	13	:	21
Using other online health services via a website or app instead of having to go to the hospital or visit a doctor, for example getting a prescription or a consultation online	:	:	:	:	:	:	:	:	:	:	:	:	:	15
Accessing personal health records online	:	:	:	:	:	:	:	:	:	:	:	:	:	8
Listening to music	:	:	:	:	:	:	:	:	:	49	:	58	65	:

Base: Adults (aged 16+) in Great Britain.

: Data not available.

Source: Office for National Statistics

Note: The figure shows a screen shot of Table 5 Internet Access survey of the ONS, UK.

For our application, the only feasible course of action is to adopt the second case since the only information we have on prices is based on subscriptions. The task of acquiring reliable data on the number of subscribers to free goods is not straightforward. This type of information is not readily available from any source that we know of at this point. As such, we estimate the number of individuals who have access to videoconferencing and video calls using the ONS's Internet Access Survey and population statistics. In particular, we employ table 5 of the said survey (see figure 6). We multiply the proportion of adults with access to certain internet activities–which in our case, "Making voice and video calls", "Sending and receiving emails", and "Reading online news"–by the estimated number of individuals 18 years old and above based on the ONS' population projection data set. We arrive at the gross value of free goods by multiplying our estimated number of subscribers for each activity by their respective implied prices.

People often use multiple service providers for the same purpose. For instance, it is common that a person who uses Whatsapp for video calls would also engage the services of other videoconferencing providers such as Facebook Messenger or WeChat. One can argue that the utility received by individuals from the use of one service provider is separate from the utility it derives from another provider[8]. In the case of market goods, if a person is subscribed to both Netflix and Disney Plus, a subscription to the two services would be counted separately in GDP and HFCE.

Ideally, the best way to achieve this is by employing the number of users for each service provider. Unfortunately, precise data on the number of users are not readily available. The top two providers of videoconferencing service (in terms of user share) in the UK are Whatsapp and Facebook Messenger (see Statista Research Department (2021b)). The top two most downloaded videoconferencing applications in the UK are Whatsapp and Telegram (see Statista Research Department (2021a)). We employ the number of Facebook Messenger users published by Statista Research Department (2022) and Statista Research Department (2021c) for the number of Whatsapp users. We impute for the number of telegram users by taking the proportion of Telgram downloads to Whatsapp downloads in Statista Research Department (2021a) and apply the ratio to the number of Whatsapp users for each year.

For online news, we estimate the number of individuals who read the news from the web pages of the following news sources: BBC, Sky News, The Guardian, Daily Mail, Google News, Youtube, Local Newspaper, Huffington Post, ITV, BuzzFeed, MSN, LADbible, Yahoo News, The Sun, and The Metro. We use the data on the percentage of individuals who identify as viewers for the respective source from Ofcom's 2021 News Consumption report, conducted by Jigsaw Research (2021). We multiply the share of news viewers/readers per news source with the population estimates from the ONS in order to arrive at the number of viewers/readers for each news source.

To arrive at the estimates of gross value, we multiply our indicators for the number of subscribers for free videoconferencing and online news to the price estimates we generated in section **??**. Unfortunately, we are not able to find any data on the number of users for Gmail, Outlook, or Yahoo Mail (the top three providers of free email services in the UK). As such, we maintain our earlier estimates for email.

[8]For videoconferencing, Whatsapp probably allows a person access to a network of people separate from the network provided by WeChat.

2 Supply and use framework

Figure 7: Conventional approach

	Oil Industry	Advertising Industry	Soap Industry	Intermediate Demand	**Final Demand**	**Total Use**		
Oil			10	10		**10**		
Advertising			10	10		**10**		
Soap				0	50	**50**		
Intermediate Consumption	0	0	20				**GDP**	**Total Use**
Value Added	10	10	30				50	70
Total Output	**10**	**10**	**50**					
				GDE	50		-	-
				Total Output	70			

Note: The diagram shows the use table employing the conventional SNA framework.

Figure 8: Barter approach

	Oil Industry	Advertising Industry	Soap Industry	Household Viewership	Intermediate Demand	**Final Demand**	**Total Use**		
Oil			10		10		**10**		
Advertising			10		10		**10**		
Soap					0	50	**50**		
Household Viewership/Digital Service					0	10	**10**		
Intermediate Consumption	0	0	20	0	20			**GDP**	**Total Use**
Value Added	10	10	30	10				60	80
Total Output	**10**	**10**	**50**	**10**					
					GDE	60		-	-
					Total Output	80			

Note: The diagram shows the use table employing the barter approach.