

Do-it-yourself digital: the production boundary, the productivity puzzle and economic welfare

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Abstract

Part of the debate about the ‘productivity puzzle’ concerns the potential mis-measurement of digital activities. Specific measurement adjustments explored in previous research do not make a large difference to productivity growth estimates. This paper discusses additional measurement issues, specifically digitally-enabled substitutions in activity across the conventional production boundary. Taken together, they are wide in scope. They also re-open an old debate about GDP as a welfare measure. Deflation and hedonic adjustment to calculate real GDP inherently concern economic welfare. The scale of digital change, clearly affecting economic welfare, is now so great that this debate must be revisited.

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Digital activities and business models are affecting the measurement of GDP, on existing national accounts definitions, in multiple ways. Digital change is causing a wide range of substitutions both within and across the production boundary as currently defined. Substitutions between economic activities occur all the time but it seems reasonable to think the pace has increased thanks to the rapid spread of fixed and mobile broadband. This is of interest to economists because taking account of these digitally-enabled changes could potentially increase measured real GDP and productivity.

Robert Gordon (2016) has challenged the idea that the new technologies are contributing much to either welfare or productivity. On the other hand, the digital sector insists the scale of recent innovation is such that the

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contribution of digital to the economy must be under-stated.² It is surely the case that an explanation of recent productivity behaviour will involve many contributory factors, including overhang from the financial crisis and long-term structural issues such as demographic change. But technology adoption and use would normally be expected to play a role. It would be surprising if the significant behavioural changes by businesses and households, arising from the spread in the UK and other OECD countries of broadband internet (from 2000) and very rapid take-up of smartphones and mobile internet (from 2007), with evident effects on production and consumption, had not had any noticeable impact on the economy.

Digital change poses numerous challenges for the collection and interpretation of economic statistics, ranging from ensuring newer businesses and activities are included in data collection to difficulties in taking due account of quality change in goods and services. The range of these challenges was set out in the UK's Independent Review of Economic Statistics, and addressing them is at the centre of the strategic plan of the Office for National Statistics (Bean 2016, ONS 2016d, Coyle 2015). Previous research has considered some potential contributions from technological change to the 'productivity puzzle' observed in most OECD economies since around 2008, and found them to be relatively small (for example, Ahmad & Schreyer 2016, Byrne et al 2016, Syverson 2016). For instance Byrne et al (2016) concluded the effects of quality change in ICT products and services are too small for careful hedonic adjustment to account for the break in trend productivity (partly as the size of ICT goods and services sector is small).

Yet these conclusions on the face of it seem at odds with the dramatic changes in the diffusion and use of new technologies by households and businesses. To explore the question of whether measurement artefacts might contribute to understanding the slowdown in real GDP growth and therefore productivity, the focus in this paper is on the switching of economic activity

² See for example Aeppel 2015, ONS 2016c, Varian 2016.

across the (existing) production boundary; elsewhere (Coyle, in progress), I explore digitally-driven substitutions inside the production boundary due to the lack of business model invariance of measured GDP and the implications of quality change across a wide range of goods and services for price indices (see Table 1). Online activities undertaken by the household sector and substituting for marketed activities have been growing. These activities should at a minimum be measured more fully in the household 'satellite' account; given their rapid growth, they require more careful measurement to inform assessments of economic welfare and policy.

Consideration should also be given to the interpretation of these substitutions across the production boundary. The fact that clearly productive online activities are occurring on the non-market (non-'production') side of the boundary raises the question of the usefulness of real GDP in the existing national accounts measurement framework. This goes back to the original fundamental debate about the purpose of GDP: is it simply an aggregate measure of marketed activity? In this case the issues raised here are irrelevant. Or is it intended to be a measure of economic welfare (as it is in fact used), in which case national accountants should perhaps work to take account of the various digital substitutions? The first approach has broadly prevailed since the 1940s (Coyle, 2014; Mitra-Kahn, 2011). Consumer surplus gains have by definition never been captured in GDP because it simply measures transactions at market prices. Many national accountants continue to insist this is the correct approach, and that it is a conceptual mistake to try to account for welfare changes in GDP. For example, Ahmad and Schreyer (2016) point out that production boundary issues are not new conceptually, and neither is the creation of unmeasured consumer surplus by innovations. Bos (2017) writes, "The successive guidelines all agreed that national accounts should not aim at measuring welfare, but focus on serving as a practical tool for macro-economic policy issues," while noting that there have been repeated calls over the decades for an economic welfare measure.

Yet almost all policy debate uses GDP as an indicator of economic welfare. Indeed, as soon as the nominal figures are adjusted for price changes there is an implicit welfare element – why, otherwise, should there be any attempt to hedonically adjust prices, as the very idea of ‘quality change’ goes directly to underlying preferences? Recent research (Brynjolfsson et al, 2017) to measure directly this consumer surplus from digital innovation suggests in preliminary results that it is large. Taken together, the scope of the substitutions discussed in this paper, and of the substitutions, new products and quality change occurring within the production boundary that I discuss elsewhere, is significant. Some of the individual substitutions would tend to reduce rather than increase the measures of labour or multifactor productivity on current definitions, so it is not obvious without much statistical work that they can resolve the ‘puzzle’. However, many of them have implications for the construction of deflators. Taking these into account could mean that nominal GDP may be over-deflated, and real GDP growth and productivity may therefore be under-stated.³ To the extent that the developments have increased over time, this could contribute to the productivity puzzle debate.

This old debate has significant implications. It is central to the practical question of what statistical offices should be doing in response to the digital change that is one of the most visible features of current developments in the OECD economies. It also speaks both to the policy interpretation of productivity statistics, and to the increasingly often-expressed dissatisfaction with GDP growth at all as a yardstick for economic policy.

³ Throughout I use ‘real’ and ‘nominal’ as shorthand in place of the terminology of the SNA, ‘in volume terms’ and ‘in current price terms’ respectively.

Table 1 Examples of digital changes raising measurement issues

I Activities in HHSA – substitution across the production boundary	
DIY digital intermediation	Substitutes for (some elements of) market intermediation; new models of intermediary & their location; use of household capital. Should be treated symmetrically with owner-occupier housing services if of sufficient scale?
Sharing economy	Data collection; use of household capital. If marketed, in principle in GDP; if not, in HHSA.
Voluntary household production of digital products	Substitutes for marketed output; should be included within production boundary? Measurement of household capital and resultant capital services.
II Activities within the production boundary – affected by digital business models	
Sampling	Prices of digital equivalent goods; outlet substitution bias.
Composition effects	Shift in industry composition especially to hard-to-measure sectors
Intangibles	Hard to measure, increasingly included in investment statistics; Consider value of information stored in databases
Digitisation of products, digitalisation of business models	Reducing sales of some marketed products Many zero price goods; Reduced fixed investment in commercial property (higher sales/bricks ratio, greater productivity of brick services) Use of cloud services 'Factoryless' manufacturing
Second hand goods	Nets out of HHFCE (apart from dealer's margin if 3 rd party involved) but may be substituting for some new purchases, with lower prices.
Ad-funded free goods	Same in principle as commercial TV, bigger in scale Deduct an imputation for cost of watching ads? Substitution between ad-funded vs subscription vs purchase to own consumption
Cross-border effects	Substitution between different national GDP totals as users switch to overseas intermediaries – data collection issues; Attribution of value added in digital value chains.
III Activities within the production boundary – new goods, quality changes and price/volume split	
ICT hardware	Sector is small, no acceleration; Smartphones hedonically adjusted for some features but not for vast expansion of capabilities; Other price strategies
ICT services	Cloud computing, communication services, etc. Not hedonically adjusted but there has been significant scope and quality change; Free goods eg operating systems
New goods	Old problem a. Lower prices from new business models eg hotel prices & Airbnb; b. New digital goods (is a download a new product or a better CD?); c. prices of bundled products; d. Boundary between consumer surplus and quality change ie. when does it make sense to try to measure value at the margin? e. distinguishing real (physical) from real (constant exchange value) & impact of chain weighting?

Production boundary paradoxes in the national accounts framework

A key decision in the definition of GDP and the standards embedded in the present System of National Accounts was where to draw the line in terms of what is included and excluded. Broadly speaking, the line – the production boundary – distinguishes paid-for activities in the market economy from unpaid activities, which are considered outside the productive sector. However, there are activities that by convention blur the boundary. One obvious one is that government activity is included in GDP although by definition it is not in the market, a convention intensely debated both in principle in the early debates and in terms of detailed practice in the implementation of successive SNA revisions.⁴ In the present national accounts framework, broadly speaking firms and the government are considered producers for the purposes of inclusion in GDP, and households are not (although non-marketed productive activity takes place within households and unincorporated enterprises are included in the household sector).

The production boundary is defined in the following way. Included are:

- a. Goods and services produced for supply to ‘units’ other than their producers;
- b. Own-account production of *goods* retained by their producers for final consumption or capital formation;
- c. Own-account production of *knowledge-capturing products* retained by their producers for final consumption or capital formation (but excluding such products produced by households for their own use eg family photos);
- d. Own account production of housing services by owner occupiers;
- e. Production of domestic and personal services by paid domestic staff.

Own-account production of services is excluded on the grounds that these have, “Limited repercussions on the rest of the economy,” changes in their level do not affect the economy’s tax yield, and there are no market prices at which to value these services (SNA 2008, paras 6.27-6.30). As noted below,

⁴ Mitra-Kahn (2011) surveys the debate; on this point see also Lacey (2011); Studenski (1958) Chapter 14; Vanoli (2005) p249ff.

this reasoning seems at odds with the growth of market equivalents of many household services, leading to significant and in some countries continuing shifting of activity across the production boundary since the 1970s.

Conceptually, the household can be considered a production unit combining inputs of its own time (labour), household capital assets (ovens, cars), and purchased intermediate or final goods and services, to produce or secure a range of final goods and services which in the majority of instances the household itself consumes, but which can also enter the productive economy (Becker 1965, Abraham and Mackie 2005). There is a range of possible choices, for example from growing vegetables and cooking everything from scratch at home, to buying food and hiring a cook or eating all meals in restaurants. Over time, as real wages for work outside the home have increased and social change has led more women to work in paid employment, the opportunity cost of home production has increased, and substitution from home production to market production has occurred. This has accompanied investment in domestic capital – such as washing machines – increasing household labour productivity.

As described above, the production of *goods* by households for their own consumption is by convention included in the definition of GDP, whether they are sold in the market or not. This reflects the importance of own-production of food and clothing, for instance, in low-income economies. “When the amount of a good produced within households is believed to be quantitatively important in relation to the total supply of that good within the country, its production should be recorded,” (SNA 2008 §6.233). Goods such as these were considered ‘near market’ as a third party would be able to provide them to the household; and there would be market prices enabling them to be valued. However, the production of *services* (childcare, cooking, cleaning and so on) for own-consumption is excluded (although services provided by paid domestic staff are counted in GDP). The distinction, or ‘nearness’ to market of own-produced goods as opposed to services was

much debated in the early days of the establishment of national accounting standards. In his classic history, Paul Studenski (1958) wrote: “Most scholars favour, *in principle*, the inclusion of the unpaid services of the housewife in national income. The difficulty, however, consists in finding a fair measure of the economic value of the housewife’s services,” although he added the caution that care should be taken not to try to annex too many own-account activities to national income (Studenski, p177). Such services are productive, in that they are provided for other people, but not counted within the SNA production boundary.

Finally, the ‘own-account production of housing services by owner-occupiers’ is also included in GDP, in the form of an imputed value for the market rent owner occupiers would otherwise have to pay for housing.⁵ Studenski noted that an imputation for owner occupied housing services had not previously been widely included in definitions of national income. From 1944, however, it was incorporated into the international standard: “Home ownership was assumed to be a business, producing services that are sold to the home owner in his capacity as tenant,” (Studenski p178). While almost certainly pragmatically motivated by the fact that the UK (a key player in the postwar national accounting debates) levied tax on the imputed rental of owner-occupied housing until 1963/4 (the ‘Schedule A’ tax), this change was justified with reference to the obvious ease of switching between owning and renting, and the potentially large impact on measured GDP of decisions to switch mode of occupation. There is no difference in principle from the decision to go to a launderette rather than use the washing machine at home, but the boundary between owning and renting a house can be clearly identified, and moreover there is a difference of scale, which is not relevant in theory but does matter for practical statistical purposes. The consequence is that a component of GDP consists of a non-monetised service derived from household capital; this is the only household capital asset currently accounted for.

⁵ <http://unstats.un.org/unsd/nationalaccount/sna2008.asp>

As Vanoli (2005, p242) summarises it, with the prominent exception of imputed rental of owner occupied dwellings: “GDP is defined in the SNA in such a way as to represent the aggregated value of the production of goods and services within the field of socially organized employment.” This fundamental criterion of the potential for exchange explains why leisure is excluded from GDP. The definitions have evolved over time – for example in the inclusion in principle since the 1993 SNA (and 1995 ESA) of the production of illegal, marketed activities. However, definitional decisions concerning the production boundary have often been challenged. Feminist scholars have long noted that the goods/services distinction in own-production ensures activities mainly performed by women are not measured, to the detriment of social policy decision-making (Waring 1988, Folbre & Nelson 2000). The value of leisure as a component of economic welfare is not reflected in GDP, so there have been attempts to remedy this. Nordhaus and Tobin’s well-known ‘Measure of Economic Welfare’ estimated it to be the same order of magnitude as conventionally measured GDP, when valued at market wage rates to reflect the opportunity cost of leisure (Nordhaus and Tobin 1972). A more recent economic welfare measure indicates that whereas the United States has large advantage over other rich OECD economies in terms of real GDP per capita, incorporating leisure (as well as mortality and inequality) into a welfare-enhanced GDP measure almost closes the international gap, indicating the importance of choices on these margins for economic welfare comparisons (Jones & Klenow 2016).

Why there is a household satellite account

These longstanding concerns about omissions from GDP have been addressed by the development of satellite accounts. Satellite accounts measure areas of activity at least in part excluded from the ‘core’ SNA because they are outside the production boundary. Eurostat first put forward

methodological proposals for a household satellite account covering own-account production and consumption in 1999, and the ONS followed up with detailed methodological proposals and its first experimental estimates in 2002 (Holloway et al 2002).⁶ One source of data for the HHSA is a time use survey, which is combined with appropriate methods for valuing the time households spend on each kind of activity.⁷ Unfortunately time use surveys are not conducted regularly, and there are issues of quality and comparability over time in the results. ONS also implements an output approach in the HHSA as recent time use surveys are unavailable, aiming to measure directly the services provided rather than measuring the labour input to produce them. There are conceptual questions involved in valuation of home produced services when by definition no market price is available. Alternatives are to use: market wage rates to apply to time use data; the opportunity cost of the labour time involved; or the price of a near-market alternative (Abraham and Mackie 2005, Chapter 3).

Table 2: Time use patterns – an illustration

	All	Employed 30-49 hours/week	Caring for family/homemaker
Minutes per day			
Employment	176	305	8
Commuting	21	37	1
Job search	0	0	0
School/study	15	5	4
Volunteering	11	8	15
Eating & personal	134	119	133
Childcare	20	17	95
Housework/shopping	173	128	286
Socialising/entertain	63	58	62
Exercise/sport	14	14	10
Hobbies & games	21	18	14
Mass media	184	150	169
Sleep	508	499	526
Other	100	83	117
Total	1440	1440	1440

Extracted from Table1, Labour Market Trends, February 2004, based on 2000 time use survey

⁶ See <http://ec.europa.eu/eurostat/en/web/products-statistical-working-papers/-/KS-CC-03-003> for more on Eurostat's approach.

⁷ ONS carried out UK time use surveys in 2000/01 and 2014/15. Most recent UK data are available from Gershuny et al (2017), UK Data Service. In the US the Bureau of Labor Statistics conducts time use surveys on an ongoing basis, <https://www.bls.gov/tus/>.

ONS published a second full HHSA in 2016, using both time use data and a range of survey and administrative data to estimate output.⁸ The HHSA covers the value of adult and childcare, household housing services, nutrition, clothing and laundry, transport (any privately provided non-leisure transport such as commuting, shopping, school run), and volunteering.⁹ The activities included were selected according to the ‘third party criterion’, in other words whether a third party could provide these services in the market (Reid 1934). This excludes therefore self-care and leisure. Table 3 sets out the relationship between the SNA ‘core’ and the household satellite, with the lightly shaded boxes lying inside the production boundary and therefore included in GDP. Nominal values for 2014 are given in the table.

Table 3: Relation of household satellite account to core National Accounts

‘Core’ SNA	Household satellite account				
	SNA production (£1817.3bn)			Non-SNA production (£1018.9bn)	
Market production	Voluntary production (goods)	Household production for own use			Voluntary production (services) (£23.3bn)
		Own account production of goods (£0.2bn)	Housing services produced by owner-occupiers (£177bn)	Services produced for own use: childcare (£320.6bn) adult care (£56.9bn) housing services (£149.7bn) nutrition (£144.3bn) clothing/laundry (£5.6bn) transport (£235.8bn)	
A	B	C	D	E	F

⁸ The 2016 ONS HHSA (in absence of up-to-date time use data) was estimated using the output approach, using a range of survey or admin data sources to create estimates based on *units of service produced x price per unit*. When time use data is used then the input approach can be used: *hours worked x market wage rate* (plus any adjustments for market equiv tax/subsidies and gross operating surplus).

⁹ <https://www.ons.gov.uk/releases/householdsatelliteaccounts2011to2014>

Source: Table from Eurostat 2003; figures are for 2014, from ONS 2016a. Note that ‘housing services produced by owner occupiers’ refers to imputed rent for living in the property; ‘housing services’ in the non-SNA category refers to DIY delivery of building maintenance.

As noted above, substitution between activities included in GDP and excluded from it has always occurred. Since the 1950s there has been growing substitution from own-use production of services such as nutrition and childcare to purchases of such services in the market, as the proportion of women engaged in paid employment has risen. For example, as 40% of lone-parents of under-fives work and 62% of couples with under-fives are both employed, use of marketed childcare is clearly extensive. Households’ recorded annual expenditure on ‘nursery, crèche, playschools & childcare payments’ was £4.7bn in 2014, while public expenditure on child care (including tax credits) was £5.2bn. In the latest HHSA estimates published by ONS, the gross value added of all childcare services in the home was £320.6bn, and output of childcare services in the home for children under five was £132bn (32.5bn hours x £4.06 per hour in the 2014 HHSA estimates). Own-account childcare services are thus greater in scale than the imputed rental for living in owner-occupied housing.¹⁰ Scale was a practical criterion for the inclusion of an imputation within GDP for services from owner-occupied housing, in addition to the conceptual criterion of sale of home produced output in the market. The logic of substitutability – albeit a choice made before production rather than after in the case of services – could argue for other categories of home production being placed on the GDP side, or alternatively for removing the imputed rental of owner occupied dwellings from GDP and putting it with other home-produced services in the HHSA.¹¹

Digital home production

¹⁰ Family Spending, Table A1

<https://www.ons.gov.uk/peoplepopulationandcommunity/personalandhouseholdfinances/incomeandwealth/compendium/familyspending/2014-12-02/familyspending2014referencetables>;

<https://www.publications.parliament.uk/pa/ld201415/ldselect/ldaffchild/117/11706.htm>

¹¹ This is all the more significant given the impact of a tightly restricted supply of housing on house prices and therefore estimated total imputed rental of owner occupied dwellings and GDP in the UK context.

However, here I focus on newer kinds of non-SNA household production, rather than on the long-debated ones. In 2015, 80% of adults in the UK went online daily.¹² The Bean Review noted that there has been an increase in households performing for themselves online more services previously purchased as a service in shops, such as booking holidays or undertaking banking transactions; there is still a supplier of a marketed service (although the identity of the intermediary may have changed from a traditional high street agent to an online platform). However, some elements of the service (such as search and assembly of holiday packages) are now performed by the individual using a domestic asset (a home computer or device) and inputs (an internet connection). Participation in the ‘sharing economy’ may also be increasing production activities by households for sale in the market, also involving the use of household assets such as dwellings and cars as well as labour. Thirdly, many individuals are contributing voluntary digital labour to provide digital services/products in effect as public goods which households and businesses may be substituting for purchased alternatives; examples include coding open source software, and creating user-generated content. I consider these three in turn.

Household production of digital intermediation services

Taking first the household production of services for own use, the kinds of activities in question include what might be labelled do-it-yourself digital intermediation services. These involve the substitution of online activity at home for some components of purchased services. Table 4 gives examples. Retail activities have undergone various technological and business model changes over time. In the mid-20th century a consumer might normally visit several specialist high street shops, ask for items, and be served them by a retailer. Supermarkets have largely replaced the individual grocer or butcher,

¹² ONS Internet Access Survey 2015
<http://www.ons.gov.uk/peoplepopulationandcommunity/householdcharacteristics/homeinternetandsocialmediausage/bulletins/internetaccesshouseholdsandindividuals/2015-08-06>

Table 4 Examples of household digital intermediation services

Banking	<i>56% of UK adults used internet banking in 2015</i>
Financial trading	<i>No estimate of numbers for normal personal transactions eg via 'wrapper' platforms; many 'day trading' services advertised and careers advice available: https://www.reed.co.uk/career-advice/how-to-become-a-day-trader/</i>
Insurance broking	<i>Many households search online for insurance</i>
Mortgage broking	<i>Many households search online for mortgages</i>
Travel advice & reservations	<i>46% used the web to use travel or accommodation services</i>
Estate agency	<i>Many households search online for properties; there are some online-only estate agencies</i>
Employment agency	<i>25% used the web to look for a job or send a job application</i>
Online search	<i>Almost everyone who is online</i>

Percentage figures are from ONS Internet Access Survey

substituting this paid work with the consumer's own 'work' in walking round the store and selecting items. New automatic self-serve checkout machines are now progressively replacing the paid labour of cashiers with the unpaid labour of shoppers. These transitions will look like an increase in the productivity of retailers, but the absence of an accounting for the 'home-produced' labour will overstate the 'true' productivity gain.

The growth of the new 'do-it-yourself' digital intermediation services has certainly not wholly displaced market intermediation; indeed intermediary businesses such as banks and estate agencies see the web as another channel partly replacing their conventional high street engagement with consumers. There has been a change in the identity of the market intermediaries in some of these examples, with new online (sometimes overseas) intermediaries taking market share; but there are still market transactions taking place. Even so, to some – possibly small – extent households themselves are carrying out some of the functions of the

previous high street intermediaries, such as search in travel and estate agency, or transactions such as making payments and setting up standing orders in online banking.¹³ They also use their own domestic capital (computers, tablets or smartphones) as well as the capital (IT systems) of the intermediaries. To the extent that this is the case, it will have reduced measured revenues, output and employment in the affected sectors, and hence GDP, all else being equal (although of course household expenditure will have been reallocated away from travel agents to other items, including a portion of their broadband subscription payments).

Households do though have access to a wider choice and save some time compared with their pre-digital options, although just as with other own-production of services they contribute some of their own labour time to the activities. In addition, households are engaged in new kinds of online activities for which there were previously no (or only a few) market intermediaries. An example is online search not previously possible such as looking for films or restaurants before going out, or locating suppliers ('personal concierge activities'?). This could be a large effect; Varian (2016) has estimated that the value to consumers in the US of time saved through use of online search rather than going to a library or other alternatives is approximately \$65 bn annually.¹⁴ One could argue the internet has also made positive changes to the range and quality of the services the consumer can access, but at a fraction of the cost. While in theory this should already be reflected in the national accounts, if the price deflator has been sufficiently adjusted to take account of the falling cost of a 'like-for-like' service, in practice this is probably not the case (Coyle, in progress).

¹³ It might be objected that search is not a productive activity, so the digital intermediation in this respect has simply reduced a transaction cost. To the extent this is true, it was also not part of the marketed service provided by travel agencies etc., and their marketed activities are those replaced by household production.

¹⁴<http://cdn.oreillystatic.com/en/assets/1/event/57/The%20Economic%20Impact%20of%20Google%20Presentation.pdf>

It is difficult to know from currently available statistics how much personal labour time is involved in supplying these own-account services. It may be small, but this seems an obvious information gap to be addressed by future time use surveys. These activities would fall into the same category as other own-use services such as laundry, childcare etc (column E in Table 2). Their growth will probably have involved a switch away from marketed intermediation services, although many market providers will remain, offering a changing array of services through different business models (such as personal financial advice rather than straightforward counter transactions in banking).

The 'sharing' economy

A second set of household activities involving home produced but (sometimes) marketed activities is sometimes described as the 'sharing economy' (for which there is no accepted definition).¹⁵ In Table 2 these clearly sit in the final column (F) if non-marketed, and in the first column (A) if sold in the market. The sharing platforms have two effects. Digital intermediation increases the efficiency of matching, which is a clear increase in economic welfare, to the extent that people's preferences are heterogeneous. There is also in principle an increase in the efficiency with which household capital assets are used – so for example, cars can stand idle less of the time, and fewer may be owned, releasing land currently used for parking. In the conventional national accounts framework, welfare increases not captured in market prices are irrelevant to GDP, while the dynamics of improved capital efficiency are complicated and anyway currently small in scale. The main challenges for the measurement of GDP are therefore practical rather than conceptual in terms of the existing national accounts definitions. ONS work to date has identified three categories of these market sharing economy activities, distinguished by output characteristics, as set out in Table 5.

¹⁵ This nomenclature is controversial because it extends a term originally applied to non-marketed peer-to-peer activities such as time banking and Freecycle to monetary activities. The distinction between marketed and free is certainly key.

Table 5: 'Sharing Economy' categories

Property rental and access	Airbnb, LoveHomeSwap, JustPark
Peer-to-peer services	Etsy, TaskRabbit, Lyft, Bookalokal
Collaborative finance	Zopa, Veridu, Funding Circle

These also have different input mixes, with the first category involving more intensive use of household capital, the second more use of labour, and the third financial capital. There are in addition sharing activities that do not involve any financial transactions (such as Freecycle, Olio, or neighbourhood time banks), which will substitute for some marketed activities.

One challenge is simply the collection of data on these activities. Platforms growing rapidly may not be included in samples currently; the ONS intends to collect additional data in future: “To pursue the collection of survey data on the sharing economy we are introducing new questions on both the Internet Access Survey for households and individuals, and the E-commerce Survey for businesses. These questions will provide data on the proportion of adults and the proportion of businesses that have arranged accommodation or transport services via platforms such as Airbnb, SpareRoom, Uber and Lyft. These data will provide important indicators on the prevalence and growth of these activities.”¹⁶ To measure the peer-to-peer activities, the intermediation revenues of both the platforms (businesses such as Lyft and Airbnb), the earnings of individual participants (drivers, hosts), and the expenditure by service users need to be collected. So too prices in the sector. In principle, all fall within current definitions of GDP and price indices, and it may be that the availability of corporate platforms will enable better measurement in the sense of formalising some previously informal transactions. Again, these digital business models may have implications for price indices; their prices are generally not included in the sampling for consumer price indices, and if they were to be included through the usual matching process or as a new

¹⁶<https://www.ons.gov.uk/economy/economicoutputandproductivity/output/articles/thefeasibilityofmeasuringthesharingeconomy/progressupdate>

good, the resulting index would omit a substantial part of the price reduction available (Groshen et al, 2017). The significance of this depends on the extent to which people are switching to such services.

Another practical challenge is the extent to which these activities involve purchases of intermediate goods, which ought in principle to be netted out, and also use the services of household capital assets, of particular relevance when it comes to looking at productivity measurement. Just as business purchases of intermediate goods need ultimately to be netted off final revenues in the GDP figures, so with production for the market by households; and this is in fact done in some of the HNSA categories. Extending this is a tall order: how for example could one begin to measure purchases of household cleaning products for use in cleaning a room rented out on Airbnb rather than for domestic use? However, there are new supply chain services emerging in the largest segments of the 'sharing economy', such as intermediaries that will look after cleaning and key transfer for properties. It will be more straightforward to collect this data.

When it comes to assets, treating the equipment purchased as investment would affect GDP; as noted, at present owner occupied housing is the only household asset to feature in national account statistics, in the form of the imputed rental paid for the capital service. While housing is the largest asset by value owned by the household sector, many sharing economy activities involve the use of cars, computers, sewing machines, perhaps even 3D printers in future (although it is unlikely many households will want to own a 3D printer, it will be an obvious asset for sharing). All of these are productive durable assets providing a stream of services. As long as such peer-to-peer activities within the household sector remain small scale, the omission of capital services from household assets will not be significant. If they were to grow, this would be an issue for estimates of multifactor productivity.

The scale of the sharing economy may still be small, although it has been growing rapidly. However, ‘contingent’ employment patterns in general are becoming significantly more widespread: although there is no definitive way of measuring it, relevant indicators such as self-employment, zero hours contracts, and industry figures point to significant expansion in the past decade or so (Coyle 2017a).

Voluntary digital production

The third category of household production where digital is starting to have a big impact is in the voluntary provision of digital outputs. There is an apparently rapidly-growing category of free digital services or products provided by the voluntary unpaid labour of individuals (although to some extent individuals may seek to monetise these activities, for example by signing up to receiving advertising revenue from videos uploaded to YouTube, or increasing future earnings through building their status in online fora).¹⁷

Table 6 gives examples.

Table 6 Examples of unpaid digital provision

Type	Examples	Marketed substitutes	Scale?
Open source software	R, Python, Apache, Linux, Mozilla	Proprietary software eg Windows, Stata, IOS	Linux largest installed base of general operating systems; About 50% of web servers globally run Apache. For growth in use of R see http://r4stats.com/articles/popularity/
Online software/tech advice	Stack Overflow, SourceForge, GitHub, ...	Consultancy, software services	“With the tools we provide , developers on SourceForge create powerful software in over 430,000 projects ; we host over 3.7 million registered users. Our popular directory connects more than 41.8 million customers with all of these open source projects and serves more than 4,800,000 downloads a day”
Writing/editing	Wikipedia; blogs	Purchased	

¹⁷ There is no resolution to the long debate about whether advertising should be treated as intermediate or final consumption. See Kaldor (1940); Harrison (1999); also Nakamura and Soloveichik (2015) for a discussion of ad-funded digital media more generally.

online material		reference works, books, magazines etc	
Uploading videos, other entertainment	YouTube; social media	Purchased entertainment	300 hours uploaded to YouTube every minute; 3.25 billion hours watched globally per month. Average 6 hours/week spent on Facebook.
Other advice, discussion forums	MumsNet, health advice forums	Subscriptions to clubs	
Educational material	Khan Academy, CORE Economics, lecture videos and podcasts	Textbooks, tutors	Khan Academy used by 2m teachers and 40m students monthly. Number of free educational downloads from iTunes U passed 1bn in 2013.
Crowdsourced information, user-generated content	Waze, congestion & travel information	Local radio; or not previously available	
User/open innovation & design		Did not previously occur – serves initially small markets, commercialised as the markets grow	Von Hippel's (2017) surveys suggest it is extensive. Some likely to remain non-commercialised as potential markets are small.

As with household production for own-use, the time spent on these activities and its valuation could be accounted for, although there are caveats. For example, the distinction between leisure and productive activity for use by others is not at all clear in some of these examples. Given that people have a fixed amount of time available, the amount they spend on unpaid digital activities will be taken from other activities. This could include their paid work, with such activities perhaps seen as contributing to their experience and productivity or their status; or their leisure time (watching TV, going to the cinema); or other household activities (cooking and gardening, other volunteering). The valuation of time spent on digital production would probably be higher than the valuation of time spent on any of these alternatives if using a market substitute approach; but valuation will be particularly tricky because many of these zero priced products are public goods (non-rival in consumption) and also durable (able to be consumed over long periods).

There is also perhaps a question as to whether household provision of these unpaid digital activities to other parties should be considered as household provision of *voluntary services* (F), or as household provision of *goods* with close market substitutes (D). Typical voluntary services have included examples such as working in a local charity shop, volunteering in schools, acting as a trustee or governor, and so on. All involve unpaid time substituting either for paid labour or for the non-provision of the activity in question. In the most recent HHSA, the estimated value was relatively small. If providing these new digital products is considered a voluntary service – because they are free – they should not count in GDP. Equally, if those providing them regard the activity as an enjoyable hobby, it could be classified as leisure.

Which is the right classification for this unpaid digital activity? Although intangible and therefore often considered as services, not least because their production is highly labour intensive, there is a case for considering them to be intangible *goods*, as their consumption can be postponed and undertaken at any time and they require zero *marginal* labour input. They are often close substitutes for marketed digital and non-digital products classed as goods (packaged software, encyclopaedias, books and magazines, DVDs). They could be marketed after production. Some economists have argued that these unpaid activities are an economically efficient mode of production of goods and services in contexts where information asymmetries and transaction costs inhibit either market or managerial organisation of production, but individuals have sufficient motivation to produce for ‘the commons’ (Lerner & Tirole 2005, Benkler 2002). (An alternative approach would be to include voluntary services in the production boundary as they are clearly produced by households for the use of other people, and would seem to fall within the definition of the production boundary in SNA 2008 (para 6.27a). In that case, this question of how to classify the voluntary digital activity would not be relevant.)

The interaction of the household commons with market activities in the national accounts is somewhat complicated, certainly more complicated than the straight substitution of own-use provision of services for marketed alternatives. What's more, the scale of these activities could be large, but it is difficult or impossible to assign them to a national territory.

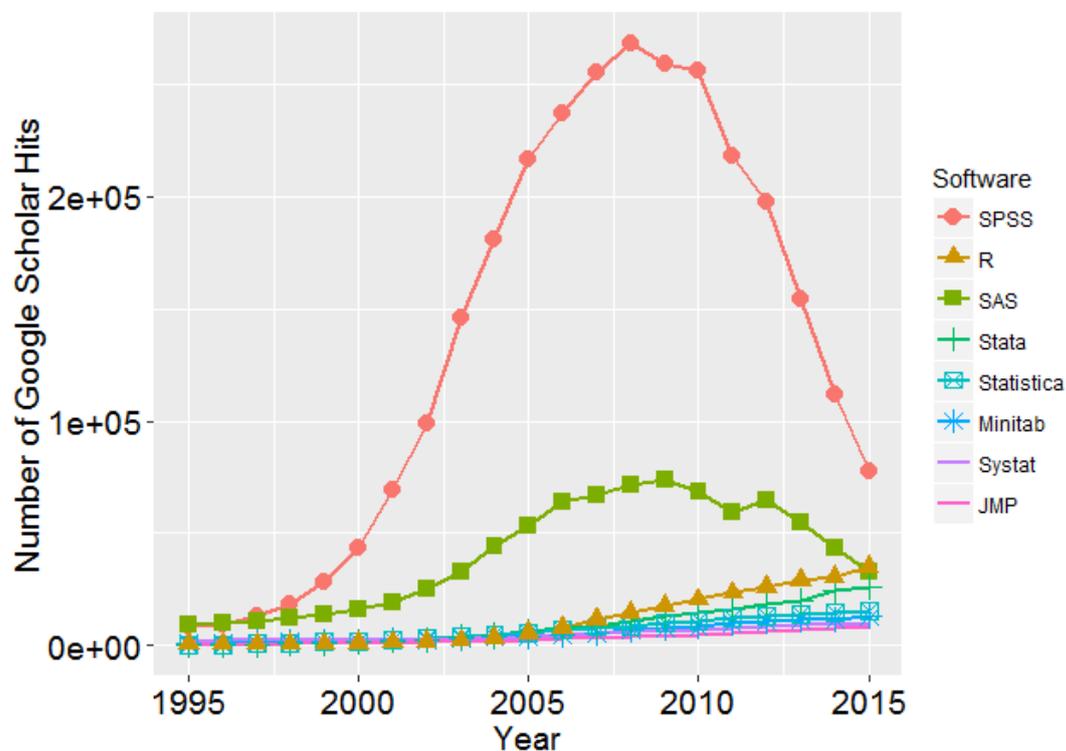
In practice, if the principle is accepted that these activities are produced by households for consumption and could be marketed, so could merit inclusion in GDP, the question in practice is whether they are now of sufficient scale to undertake a very challenging data collection and valuation programme. The scale question, the extent to which these products are substituting for marketed versions, is relevant also to assessing the productivity puzzle, as the zero price should enter the relevant deflators.

There are no readily available statistics on either personal or business use of these various digital products provided for free. Greenstein and Nagle (2014) estimate that the use of just one product, Apache, in the US equates in value to between 1.3% and 8.7% of the stock of private investment in pre-packaged software. There ample anecdotal evidence of for instance the rapidly growing use of open source software, including by large companies such as Walmart and Netflix.¹⁸ The cost savings businesses can make by switching to open source software are significant.¹⁹ Tallying downloads of the different forms of free software and estimating the impact on proprietary alternatives is nigh on impossible, but some suggestive evidence is provided by Robert Muenchen (2017). For instance, he presents figures on the number of scholarly articles listed each year on Google Scholar on the top six packages. These and other indicators (such as job listings and some downloads data, and points to possible substitution (Figure 2).

¹⁸ <https://www.linux.com/news/enterprise-open-source-programs-flourish-tech-and-elsewhere>

¹⁹ <http://www.computerweekly.com/news/450401822/Open-source-no-longer-scares-the-enterprise>

Figure 2: Top six software packages on Google Scholar



Source: Muenchen (2017)

Even if some definitive raw statistics were available, the problem of assignment within the national accounts and satellite accounts would be made more complex by the fact that household contributions merge inextricably with foundations and non-profits. For instance, two New Zealand university lecturers originally developed the R software, although other individuals were responsible for much of the subsequent development, while Apache was created by a group of friends who later formed their joint enterprise into a non-profit foundation.

The household production of say vegetables or crops, is included in GDP on the basis that this is an important component of some types of economy, and can readily be marketed. Should household production of digital products that are an ever more important component of many economies not be included on the same reasoning? There seems to be some rationale for including an estimate of production by households of these digital goods,

given their scale. However, there is an important distinction because of the public good character (high up-front production cost but zero marginal cost and zero price) of the digital products. The value recorded in GDP ought to be only the consumption or use of digital products (whereas almost all own-account production of vegetables will be consumed). It might be possible to include usage estimates of digital products, valued at the price of close marketed substitutes, for some but not all of the categories of digital production. The case for considering this seems strongest for products clearly being used as direct substitutes for marketed equivalents.

In the light of this discussion, Table 7 suggests some hypothetical rearrangements of the relationship between the 'core' SNA and HNSA. For example, the creation by households of digital products is here included within the production boundary, on the grounds of very close substitutability for marketed equivalents and scale of importance in the economy; it is in the light shaded column below and thus included in GDP. Housing services produced by owner occupiers (the imputed rental measure) and other household production of services for own use (darker shaded) are treated as equivalent. Either both could be included in GDP, via an imputation; or both could be excluded.

These classification issues are not straightforward. Bean (2016, p95-96) writes: "Maintaining a clear distinction as to whether an entity is acting as a consumer or a producer is important for the accurate classification of economic activity." However, the possibility of making a clear distinction is diminishing due to the digitally-enabled changes in consumption and production. This is for the several reasons noted here – not to mention that thanks to digital communication technologies the boundary between work and leisure is fuzzier in general (answering office emails at home, more enjoyable work).

Table 7: Relation of household satellite account to core National Accounts: alternative categorisation

'Core' SNA	Household satellite account				
	SNA production		Both either SNA or non-SNA production		Non-SNA production
Market production	Voluntary production of goods (including digital)	Household production for own use			Voluntary production of services
		Own account production of goods	Housing services produced by owner-occupiers	Services produced for own use: Childcare adult care housing services nutrition clothing/laundry transport	

Source: adapted from Eurostat 2003.

The point is that there is, in some cases, considerable substitution between an existing marketed (digital or non-digital) product and a free digital product. This allows the money that would have been spent on, say, proprietary software, to be used to purchase other goods and services, so nominal GDP will be unaffected; but the substitution has implications for the calculation of price indices. I consider this further in Coyle (in progress).

The discussion so far has been focused largely on the production side of the national accounts, but the digital activities being considered will also have implications for the expenditure and income approaches. The suggestion above was that own-account output of digital products could be valued at a shadow price such as the market wage rate for similar activities (in theory netting off intermediate purchases but in practice ignoring these as sufficiently small in scale). Real output will therefore be higher than if the free digital products were not being produced and used. The growing use of these voluntarily provided free digital products will be leading to a substitution away from paid-for products and services on the expenditure

side. Businesses and households who would have bought, say, proprietary software, can use the money saved to purchase something else. The composition of final expenditure in nominal terms will change. The true price of the total basket of goods and services will be lower as the use of the free digital goods increases: I can use £100 to buy the same basket as before plus a piece of software at zero market price but with an additional shadow value. On the income side, the shadow value of the digital production activity would need to be included for the three sides to balance, even though the producers would not be receiving a direct monetary payment for their work. This seems odd, but might perhaps be justified in terms of the reputational reward or inherent utility people derive from producing these zero price (and therefore zero monetary income) products.

The complexities involved in this are a good reason for concluding against moving these activities inside the production boundary; but the issue of substitution between marketed and non-market activities is potentially important, not least for interpreting the productivity puzzle, and means it would be useful to have a better understanding of the scale of the voluntary digital production.

Finally, there is obviously nothing new conceptually about substitutions between activities in the economy, and the potential implications for price indices. The new issues here concern whether the cross-production boundary substitutions have been overlooked, and what the incremental gains from the substitutions might be. It is obviously the case that if households are undertaking more activities online, they are doing less of something else, probably a mix of things (Wallsten 2015). However, there is some evidence that the incremental gains are large, for example in the evidence that households' willingness to pay for broadband connections is high (Roston et al 2010).

Practical issues

The above discussion points to several practical issues.

a) Data collection

One key data collection requirement to incorporate the output component described above will be the collection additional household data in the time use survey to understand the labour inputs used to produce these digital intangible goods and services. Any further valuation of household non-market activity involves conceptually the imputed flow of utilised human capital. ONS hopes to extend the time use survey in the not too distant future. The categorisation will need to distinguish between time spent on online activities for household own-consumption, for leisure, and for ‘voluntary’ production of digital products. These would need careful piloting to ensure respondents’ answers map onto the economic categories. A significant extension of time use surveys would surely require IT-enabled data collection. There is some other existing survey material on people’s online activity. For example Ofcom conducted a large-scale one-off survey in 2016 for its ‘Digital Day’ research.²⁰ However, this is focussed on consumption of entertainment and does not include the categories needed for economic analysis. It could also be of interest to capture different activities by demographic categories.

Time use data, which is collected based on diaries, would also potentially be able to contribute to measuring the labour supply component of the types of digital activity considered so far – digital DIY intermediation, the sharing economy, and the production of open source digital products. Other potential needs for additional data collection concern the sharing economy (where as noted the ONS already has some work planned). In addition to including new intermediaries in this sector in survey samples, it could be useful to check that the collection of data on incomes and expenditures also includes the sharing economy.

²⁰ <http://www.digitaldayresearch.co.uk/media/1083/digital-day-2016-chart-deck-adults-aged-16plusin-the-uk.pdf>

b) *Valuing digital home production*

If household digital production were to be placed inside the production boundary, like household production of goods, the market value of the use of these digital products would need to be estimated. As all have near-market substitutes, one approach would be to apply, for example, the price of a similar proprietary software package to an open source product, and to an estimated quantity of downloads of the software, although there might of course be immense practical difficulties, not least geo-locating the input activity and the uses or downloads (Nordhaus 2006, Greenstein and Nagel 2015).

c) *Intermediate production*

The national accounts are based on a value added approach, whereby the value of intermediate goods used in the production process is deducted from the value of a product or service, in order to avoid double counting.²¹ Byrne and Corrado (2017) provide estimates for the US of capitalised consumer IT durables, and find significant growth in real services from consumer digital assets.

d) *Household capital assets*

Currently the only household capital asset accounted for in the national accounts is owner occupied housing, because of the imputation included in GDP as described above, and because domestic dwelling investment is captured in GDP(E). One justification for this is that a home is by far the most valuable asset households ever own. However, the second major asset owned by many households is the car. With a growing proportion of households leasing a vehicle (including through car clubs), and so the scale of the potential switch from ownership to rental or vice versa increasing, a case could be made for including imputed rentals for car owners.

²¹ An aggregate measure that does not deduct intermediate goods is Gross Output, now regularly published for the US by the BEA. See Skousen (1990).

However, there is at least one other compelling reason for considering measuring the stock of, and new investment in, other household assets. If the unpaid provision of digital products were ever to cross the production boundary and be included in GDP, a capital services measure would be required because the use of capital equipment affects household productivity. This is just as true of non-digital household services for own use: someone providing home laundry services is more productive with a washing machine than a mangle. The productivity gain is realised in the form of time saved to engage in other activities, as well as a possible quantity and quality improvement in the form of cleaner clothes, more often. Digital household services need online access to be possible at all, so households have to purchase computers and install broadband at home. Replacement investment will continue to be necessary.

A further household productivity gain will occur to the extent that households are able to use their assets to make additional income through participation in some of the 'sharing economy' platforms, for example renting out spare rooms or sharing their car. The purchase of these assets is accounted for in household consumption expenditure currently, but not the continuing capital services they provide to households; incomes from renting them out is in principle included in the income measure of GDP, although this may not be well captured by current data collection methods. The provision of services marketed to other households through these digital platforms is not currently included in the output measure of GDP.

Domestic capital is likely to become more important. As the population ages, demand for adult care will increase. It will have to be provided in the market through paid caring services or in the home through unpaid household provision by family members as now. If the latter, the use of domestic robots may increase. Other innovations such as the 'Internet of Things' and affordable 3D printing machines might extend the range of activities provided by households, expanding the own-account production of goods (which falls

inside the currently defined production boundary). Both categories are small at present. But one can imagine without going too far into the realms of science fiction – as all of these exist – automated ordering, selection and delivery of groceries, involving a mix of investments by businesses (logistics systems, delivery robots, software) and households (connected domestic appliances). The use of household capital in the form of domestic appliances has in the past increased the ‘productivity’ of household production by releasing time previously spent on housework, such as washing machines replacing washing by hand. That time can be used in paid work outside the home or in activities more valuable to households. To the extent that new generations of household capital assets become available the productivity (time saved) of household production will increase again.

e) *Quality improvements*

The substitution from marketed to household account intermediation activities may also involve changes in quality or other characteristics such as wider choice and discovery of variety. Quality change in the case of marketed goods in principle can be captured using hedonic techniques, but in this case that would be harder because there is no price for the replacement (household) intermediation service; although a shadow price for this activity could in principle be hedonically adjusted over time. As with marketed goods, it may be the case that the changes in characteristics are sufficiently large or different in character that they should be considered an increase in consumer surplus due to innovation rather than a quality change in an existing good/service.

f) *Cross-border activity*

Digital activities cross national borders with little friction, yet borders define the collection of statistics, and frame the way productivity is analysed. Many of the types of digital activity considered here are global in their production and consumption. It is not obvious how the contribution of volunteer digital production in the UK alone (say to open source software) can be measured,

on the production side, nor how easily the consumption of these digital products in the UK can be measured on the expenditure side. Measurement of time spent in production (within national borders), although unpaid, might paradoxically be the most straightforward for statisticians to assess. In the case of intermediation services, the transition to digital has led to the substitution of a domestic, bricks and mortar business by an overseas-based online business, which might anyway be using intellectual property or other intangible intra-company transfers to locate its valued added in another country. I consider the cross-border complexities elsewhere.

Discussion

I argue, in contrast to some other recent research, that measurement artefacts due to digital technologies may be making a contribution to the observed marked slowdown in productivity growth since around 2008, although the extent of this possible contribution is not clear. In addition to substitutions within the production boundary, the adoption and use of digital technologies by households and businesses involves behaviours that lead to substitutions out of GDP across the production boundary. Understanding the scale of these switches across the production boundary – in adopting free, household-produced digital products rather than marketed products, in replacing marketed intermediation services with own-account activity, or in consuming and producing via ‘sharing economy’ platforms – have implications for our understanding of the level and (to the extent they are increasing in scale) growth of ‘real’ economic activity and productivity. The digitally-enabled substitutions both within and across the production boundary imply that (beyond gains in consumer surplus) the GDP deflator may be missing zero priced products (or higher quality ones) which are direct substitutes for non-zero price alternatives. Although it is impossible at present to know the scale of these substitutions, the pieces of available evidence, from the number of downloads of free software or Wikipedia usage

to the extent of contingent forms of employment, suggest it is large and growing.

This paper has focused on substitutions across the production boundary. The issues arising from the need to select a boundary have been little debated in economics since the early days of the formation of the present System of National Accounts. However, as Simon Kuznets (1947) pointed out in his pioneering work, the selection of what is inside and outside the production boundary is vital for any assessment of long-term growth trends:

“Of the quantitatively impressive growth of total output in this country, as measured in the ordinary estimates of national income, a large part is to be associated with the extension of the business at the expense of the family sector. Consequently, one important prerequisite for a more efficient measurement of economic growth lies in the inclusion of such sectors of production that easily escape the statistical eye. As specific examples we may cite the capital formation involved in the work of American farmers in bringing virgin land into cultivation, or the work within the old- fashioned large family, so or the work within the old- fashioned large family, so much of which has been taken over in recent decades by business firms.”

To put it another way, some part of the impressive productivity growth recorded in the mid-20th century was a measurement artefact due to substitution out of household production into the market. Substitutions are currently occurring in the opposite direction, thanks to digital technologies, and may correspondingly help account for part of the lacklustre real growth performance.

The current System of National Accounts takes this as an irrelevant issue, as the task of measuring GDP is (more or less) strictly defined as production for monetary exchange. In particular, it is argued that a clear distinction must be

made between increases in economic welfare due to innovation (in goods and services or business models) and increases in marketed activities. For example, in concluding that, “From a conceptual perspective, GDP does not look to be deficient, Ahmad & Schreyer (2016) put weight on the fact that , Measures of the total value of consumer welfare such as consumer surplus are at odds with the conceptual basis of measuring GDP.” By definition, on this view, any zero priced activities should not be taken account of in measuring GDP in nominal or volume terms. Those who advocate this conventional SNA approach do not deny that digital change is important, but their preferred approach would be to extend the satellite account – in this context, the household satellite account. This could be extended in many interesting ways, including separating out households and non-profit institutions serving households (as ONS intends), treat imputed rental for owner occupied housing and rental more explicitly, value voluntary activity outside the home, and own-production of services for own use, as well of course as all the digital activities discussed here. These could even form a sub-satellite.

Valuable as it would be, this approach has drawbacks. Although national accountants often describe GDP as simply monetised production, and not an economic welfare measure, as soon as it is deflated this becomes a fiction. The use of any price index is an attempt to create a measure that holds utility constant over time (with well-known challenges about how to achieve this). Real GDP (and the economists’ shorthand is in fact more accurate than the statisticians’ ‘volume terms’ phrase) is therefore inherently a welfare concept. To the extent that deflators are constructed using hedonic methods, adjusting for quality change, the welfare dimension is all the more prominent, for it is not possible to draw a clear boundary between quality changes and consumer surplus (NBER, 1961, cited in Stapleford, 2009, p316). Others have accepted the need for welfare enhancements of different kinds to the ‘headline’ GDP figures (Jones and Klenow, 2016; Jorgenson, forthcoming). If real terms GDP is useful at all, then perhaps a wider measure of economic

welfare would be more useful still, including welfare changes arising from the highly visible changes taking place in the economy at present.

To reinterpret Robert Solow's famous comment, it is a paradox that digital is visible everywhere except the productivity figures; big changes that every individual in the OECD economies is experiencing in everyday life do not figure in the principal economic statistics. It would seem an odd approach to confine all the current economic welfare developments many people see as important (the environment as well) to 'satellite' accounts.

This is a big debate, far beyond the scope of this paper. It is hardly new either, and is well reflected in the 'GDP and Beyond' agenda.²² However, the speed and scope of digital transformation has certainly reopened the question. Furthermore, the issues I discuss here and elsewhere (Coyle, in progress) highlight the immediate need for statistical offices to look to ways of improving the collection of data related to digital activities, which will likely involve finding digital collection methods too.

²² For an introduction, see <http://ec.europa.eu/eurostat/web/gdp-and-beyond>

References

Abdirahman, Mohamed, D Coyle, R Heys, W Stewart, (2017). 'A Comparison of Demand Side and Supply Side Approaches to Deflating Telecoms Services Output', working paper.

Abraham, Katharine G. and Christopher Mackie, Editors, (2005). *Beyond the Market: Designing Nonmarket Accounts for the United States*, Panel to Study the Design of Nonmarket Accounts, National Research Council, <http://www.nap.edu/catalog/11181.html>

Aepfel, Timothy, (2015). "Silicon Valley Doesn't Believe U.S. Productivity Is Down." *Wall Street Journal*, July 17, sec. US.

Ahmad, Nadim. and P. Schreyer (2016). "Measuring GDP in a Digitalised Economy", OECD Statistics Working Papers 2016/07, OECD Publishing, Paris. <http://dx.doi.org/10.1787/5jlwqd81d09r-en>

Bean, Charles, (2016). *Independent Review of Economic Statistics: Final Report*. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/507081/2904936_Bean_Review_Web_Accessible.pdf

Becker, Gary S , (1965). 'A Theory of the Allocation of Time', *The Economic Journal* 75 (299), pp 493-517.

Benkler, Yochai, (2002). 'Some Economics Of Wireless Communications', *Harvard Journal of Law & Technology* Volume 16, Number 1, Fall, pp2-59.

Bos, Fritz, (2017). 'Uses of the National Accounts from the 17th century to the present and three suggestions for the future,' *Eurostat Review of National Accounts and Macroeconomic Indicators*, 1/2017, pp 41-72.

Brynjolfsson, Erik, Felix Eggers and Avinash Gannamaneni, (2017), 'Using Massive Online Choice Experiments to Measure Changes in Well-Being', Working Paper, MIT.

Byrne, David M, John G Fernald, Marshall B Reinsdorf, (2016). 'Does the United States have a productivity slowdown or a measurement problem?' *Brookings Papers on Economic Activity*, Spring 2016, 109-182.

Byrne, David M and Carol Corrado, (2017). 'Accounting for Innovation in Consumer Digital Services, presented at CRIW conference, Washington DC, March 2017.

- Coyle, Diane, (2014). *GDP: A Brief But Affectionate History*, Princeton University Press, Princeton NJ.
- Coyle, Diane, (2015). 'Modernising Economic Statistics: Why It Matters,' *National Institute Economic Review* No. 234 November, F4-F7
- Coyle, Diane, (2017). 'Precarious and Productive Work in the Digital Economy', *National Institute Economic Review* No 240 May 2017, R5-R14.
- Eurostat, (2003). 'Household production and consumption - Proposal for a Methodology of the Household Satellite Accounts', Statistical working paper, October 2003.
<http://ec.europa.eu/eurostat/en/web/products-statistical-working-papers/-/KS-CC-03-003>
- Folbre, Nancy & Julie Nelson, (2000). 'For Love or Money?', *The Journal of Economic Perspectives*, 14:4, 123-140.
- Gershuny, Jonathan, (2011). 'Time Use Surveys and the Measurement of National Well-Being', Centre for Time Use Research, University of Oxford.
- Gershuny, J., Sullivan, O. (2017). *United Kingdom Time Use Survey, 2014-2015*. [data collection]. UK Data Service. SN: 8128,
<http://doi.org/10.5255/UKDA-SN-8128-1> .
- Gordon, Robert, (2016). *The Rise and Fall of American Growth*, Princeton University Press, Princeton NJ.
- Greenstein, Shane and Frank Nagle, (2014). 'Digital dark matter and the economic contribution of Apache', *Research Policy*, 43, pp623-631.
- Groshen, Erica L., Brian C. Moyer, Ana M. Aizcorbe, Ralph Bradley, and David M. Friedman. (2017). "How Government Statistics Adjust for Potential Biases from Quality Change and New Goods in an Age of Digital Technologies: A View from the Trenches." *Journal of Economic Perspectives*, 31(2): 187-210.
- Harrison, Anne, 'Making Services Visible', (1999). paper STD/NA(99)26, OECD. <http://www.oecd.org/std/na/2681107.pdf>
- Jones, Charles, and Peter Klenow, (2016). 'Beyond GDP? Welfare across Countries and Time', *American Economic Review*, Vol 106, no 9, September, pp 2426-57. <http://pubs.aeaweb.org/doi/pdfplus/10.1257/aer.20110236>
- Jorgenson, Dale, (2017). 'Production and welfare: progress in economic measurement', working paper
https://scholar.harvard.edu/files/jorgenson/files/jel_economic_measurement_manuscript_revised_5_05_2017.pdf

- Kaldor, N, (1950). 'The Economic Aspects of Advertising', *Review of Economic Studies*, Volume 18, Issue 1, 1 January, Pages 1–27, <https://doi.org/10.2307/2296103>
- Kuznets, Simon, (1947). 'Measurement of Economic Growth', *Journal of Economic History*, Vol. 7, Supplement: Economic Growth: A Symposium, pp. 10-34
- Lerner, Josh and Jean Tirole, (2005). 'The Economics of Technology Sharing: Open Source and Beyond', *Journal of Economic Perspectives*, Volume 19, Number 2, Pages 99-120.
- Mitra-Kahn, Benjamin, (2011). 'Redefining the Economy: A history of economics and national accounting', Ph.D. thesis, City University London. <http://openaccess.city.ac.uk/1276/>
- Muenchen, Robert A, (2017). 'On the Popularity of Data Analysis Software', <http://r4stats.com/articles/popularity/>
- Lacey, James, (2011). *Keep From All Thoughtful Men: How US Economists Won World War II*, Naval Institute Press.
- Nakamura, Leonard and Rachel Soloveichik, (2015). 'Valuing "Free" Media Across Countries in GDP', Working paper 15-25, Federal Reserve Bank of Philadelphia, July 2015.
- Nordhaus, William and James Tobin, (1973). 'Is Growth Obsolete?' in *Economic Growth*, NBER, New York, 1972; also published in *Conference on Research in Income and Wealth*, Volume 38, Publisher NBER, New York, (1973).
- Nordhaus, William, (2004). 'Principles of National Accounting for Non-Market Accounts', in *A New Architecture for the US National Accounts*, pp143-160, University of Chicago Press. <http://www.nber.org/chapters/c0135.pdf>
- Ofcom, Digital Day Research, (2016). <http://www.digitaldayresearch.co.uk/media/1083/digital-day-2016-chart-deck-adults-aged-16plusin-the-uk.pdf>
- ONS, (2002). 'Household Satellite Account (Experimental) Methodology', Holloway, S, et al, April 2002.
- ONS, (2016a). Household Satellite Accounts 2005-2014, April 2016. (2016a)
- ONS, (2016b). 'The feasibility of measuring the sharing economy: progress update', <https://www.ons.gov.uk/economy/economicoutputandproductivity/output/articles/thefeasibilityofmeasuringthesharingeconomy/progressupdate>

ONS, (2016c). Measuring output in the Information Communication and Telecommunications industries
<https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/labourproductivity/articles/measuringoutputintheinformationcommunicationandtelecommunicationsindustries/2016>

ONS, Economic Statistics and Analysis Strategy, September 2016,
<https://www.ons.gov.uk/methodology/classificationsandstandards/economicstatisticsclassifications/economicstatisticsandanalysisstrategy> (2016d)

Reid, M. (1934). *Economics of Household Production*. New York: John Wiley

Rosston, Gregory, Scott Savage, and Donald Waldman. (2010). "Household Demand for Broadband Internet Service." *B.E. Journal of Economic Analysis and Policy* 10 (1): September 9.
<http://www.degruyter.com/view/j/bejeap.2010.10.1/bejeap.2010.10.1.2541/bejeap.2010.10.1.2541.xml?format=INT>

Skousen, Mark, (1990). *The Structure of Production*, New York University Press, New York.

Studenski, Paul, (1958). *The Income of Nations*. New York University Press, New York.

Syverson, Chad, (2016). 'Challenges To Mismeasurement Explanations For The U.S. Productivity Slowdown', NBER Working Paper 21974, February 2016.

United Nations, (2008). System of National Accounts.
<http://unstats.un.org/unsd/nationalaccount/sna2008.asp>

United Nations, (1993). System of National Accounts.
<http://unstats.un.org/unsd/nationalaccount/sna1993.asp>

Waring, Marilyn, (1998). *If Women Counted*, Harper & Row.

Vanoli, Andre, (2005). *A History of National Accounting*, IOS Press, Amsterdam.

Varian, Hal, (2016). 'A Microeconomist Looks At Productivity: A View From the Valley', Brookings Institute presentation September 2016.
<https://www.brookings.edu/wp-content/uploads/2016/08/varian.pdf>

Wallsten, Scott, (2015). 'What Are We Not Doing When We Are Online?', in *Economic Analysis of the Digital Economy*, Avi Goldfarb, Shane M. Greenstein, and Catherine E. Tucker, editors, University of Chicago Press, pp55-82. <http://www.nber.org/chapters/c13001.pdf>