

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

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

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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 appear not to make a quantitatively large difference to real GDP or productivity growth estimates. However, although these potential adjustments may be small individually, taken together they could be wide in scope and quantitatively significant. This paper sets out a taxonomy of the range of potential measurement artefacts arising from digital innovations. It also specifically considers digitally-enabled substitutions in activity across the production boundary. I argue that these, along with other substitutions occurring within the production boundary, go beyond the effects of digital considered in earlier research; and may be making a meaningful contribution to the productivity puzzle as measured on existing statistical definitions.

Key words: digital, production boundary, productivity

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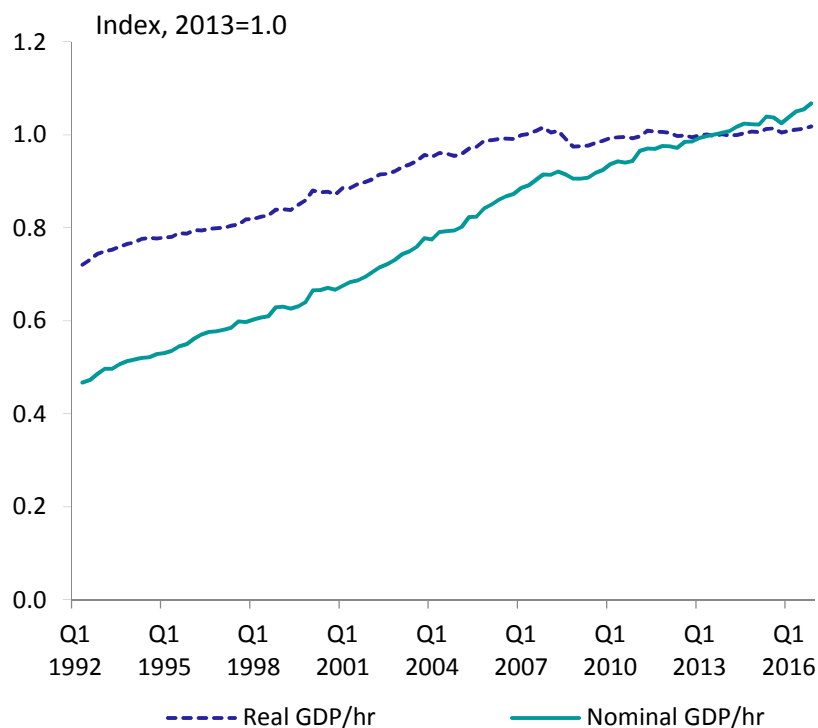
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Digital activities and business models are affecting the measurement of GDP, on existing national accounts definitions, in multiple ways. This paper makes the case that digital change is causing a wide range of substitutions both within and across the production boundary (as currently defined). Counterfactual GDP and productivity growth without any of these digitally-enabled changes would be higher than they are as measured on current definitions, although it is impossible to know by how much without further data collection.

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.² The focus in this paper is on the switching of economic activity across the production boundary; a companion paper explores substitutions within the (existing) 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.

A hint that, contrary to some other recent research,³ measurement is one of the issues at the heart of the productivity puzzle lies in the contrast between GDP per hour worked in nominal and real terms; while the growth of the former has slowed since 2008, the latter has flat-lined (Figure 1). This implies that an explanation of the 'puzzle' needs to explore the price/volume split to explore the apparent change in the behaviour of the deflator in the past decade.

Figure 1: Real and nominal GDP per hour worked



² Bean 2016, ONS 2016d, See also Coyle 2015.

³ For example, Ahmad & Schreyer 2016, Byrne et al 2016, Syverson 2016.

It is surely the case that an explanation of recent productivity behaviour will involve many contributory factors, including any overhang from the financial crisis and long-term structural issues such as demographic change. But technology adoption and use can also be expected to play a role, and part of the ‘puzzle’ lies in the contrast between the lacklustre productivity figures (in most OECD economies) and continuing rapid advances in technology, especially digital. There are in fact three sets of issues related to digital, each involving significant conceptual, definitional and practical questions.

The first set of issues, discussed in this paper, concerns the growth of online activities undertaken by the household sector that are blurring the traditional ‘production boundary’, or distinction between monetised economic activities, counted in GDP at their exchange value, and non-monetised activities, which are not in GDP. Some production boundary paradoxes are well-known. For example, paying a gardener adds to GDP but doing the gardening oneself does not. Online access has expanded the amount of unpaid service activity undertaken by households, substituting for marketed activities currently captured in GDP. Here I propose that these activities should be measured explicitly in the household ‘satellite’ account; a more radically alternative would be to add an imputed value for them to GDP.

In particular, there is a question as to whether one category of household digital activity, (for example open source software or the provision of online entertainment such as videos and blogs, which are close substitutes for marketed products such as proprietary software or paid-for entertainment), is large enough in scale to be included on the national accounts side of the production boundary, just as household production of certain physical goods (such as home grown food in low-income countries) is already included in GDP. In either case, it is important to try to understand the scale of the substitutions out of GDP that are occurring due to these digital activities (although is not easy either to draw a clear boundary between household production of such digital goods and production done as part of or in the margins of paid work).

In a separate paper (in progress) I look at how the development of new digitally-enabled business models might be altering GDP due to a lack of business model invariance. The changes include: ad-funded free digital goods and services; cross-border value chains, the location of intangible investment, and its treatment in imports and GDP; the switch from high street to online retail and other services; the growth of second hand sales replacing new sales. In all these cases an activity included in measured GDP is being progressively substituted by activities that are not included. In many of these examples, the conventions about the distinctions between intermediate goods (netted out of GDP) and final goods, or between domestic investment and imports, do not map well onto the creation of digital value added. A further important issue is whether the improved quality of digital goods and services is adequately captured in measuring prices. The challenge of hedonic adjustment of prices for products that are improving rapidly in quality is well-known, particularly in the case of technology products. In their case, though, as there have been rapid improvements for a long period, hedonic adjustment is unlikely do much to explain the observed productivity slowdown in the more recent past. However, I argue that the *scope* of quality change in products, and introduction of new products, is wider than previously considered. It is therefore likely nominal GDP is being over-deflated, and real GDP growth and productivity may be under-stated.

Previous research has considered some of these potential contributions to the ‘productivity puzzle’, the unexpectedly slow growth in labour or total factor productivity, in most OECD economies since around 2008, and found them to be relatively small. Byrne et al (2016), for example, 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 size of ICT goods and services sector is small). 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. Research under way (Brynjolfsson et al, in progress) to measure this consumer surplus directly suggests in preliminary results that it is large, but consumer surplus gains have by definition never been captured in GDP because it measures transactions at market prices. Moreover, Robert Gordon (2016) has famously 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 contribution of digital to the economy must be under-stated.⁴ It would be somewhat surprising if the significant behavioural changes by businesses and consumers, 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), had not had any noticeable impact on the economy.

I argue that the scope of the measurement issues involved may in fact be significant even if individual elements are small. Table 1 presents a taxonomy of a wide range of substitutions and quality changes due to digitally-driven change in the structure of the economy.

This paper focuses on the first category, the production boundary questions. Even though the conceptual issues are well known, the specific question here concerns digital activities that are creating a significant new margin of choice for households between market and non-market activity. Have they either become quantitatively sufficiently important either to warrant inclusion in GDP, according to the existing SNA standards (just as imputed rent is included now), or if not meeting that threshold do they nevertheless require more careful measurement in the household satellite account to inform assessments of economic welfare and policy decisions? A key issue is scale, as the *principle* of including sufficiently large household activities in GDP has already been embedded in the current definitions, although in practice only imputed rent is included, but not any other household production of services such as childcare.

⁴ See for example Aeppel 2015, ONS 2016c, Varian 2016.

Table 1: Scope of digital changes raising measurement issues

<i>I Activities in HHSA – substitution across the production boundary</i>	
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 ^(a) .
Voluntary household production of digital products	Substitutes for marketed output; should be included within production boundary? Measurement of household capital and resultant capital services.
<i>II Activities in GDP – affected by digital business models</i>	
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 investment in <i>databases</i> ?
Digitisation	Reducing sales of some marketed products; Many of these are zero price goods; Reduced fixed investment in commercial property (higher sales/bricks ratio, greater productivity of brick services)
Second hand goods	Nets out of HHFCE ^(b) (apart from dealer's margin) but may be substituting for some new purchases.
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 consumers switch to overseas intermediaries – data collection issues; Attribution of value added in digital value chains.
<i>III Activities in GDP – quality changes and price/real split</i>	
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	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?

(a) HHSA: Household satellite accounts.

(b) HHFCE: Household final consumption expenditure.

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. This question was intensely debated both in principle in the early debates and in terms of detailed practice in the implementation of successive SNA revision.⁵ In the present national accounts framework, essentially firms and the government are considered productive, and households are not.

Conceptually, however, 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.

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 1993 §6.25). 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 (1958) history, Paul Studenski 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).

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.⁶ Studenski noted that an imputation for owner occupied housing services had not previously been widely included in definitions of

⁵ Mitra-Kahn (2011) surveys the debate; on this point see also Lacey (2011); Studenski (1958) Chapter 14; Vanoli (2005) p249ff.

⁶ <http://unstats.un.org/unsd/nationalaccount/sna2008.asp>

national income by pioneers such as Colin Clark and Simon Kuznets. From 1944, however, “Home ownership was assumed to be a business, producing services that are sold to the home owner in his capacity as tenant,” (Studenski p178). This change was justified by 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 there is a difference of scale. The consequence is that quite a large component of GDP consists of a non-monetised service derived from household capital; this is the only household capital asset currently accounted for.

As Vanoli (2005, p242) summarizes it, with the prominent exception of imputed rent: “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, even though the definitions have evolved over time to reflect changing judgments – for example in the inclusion in principle since the 1993 SNA (and 1995 ESA) of illegal but 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).

The household satellite account

The 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).⁷ 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.⁸ ONS also implements an output approach in the HHSA when recent time use data is 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

⁷ See <http://ec.europa.eu/eurostat/en/web/products-statistical-working-papers/-/KS-CC-03-003> for more on Eurostat’s approach.

⁸ 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/>.

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

	<i>All</i>	<i>Employed 30-49 hours/week</i>	<i>Caring for family/homemaker</i>
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 Table 1, *Labour Market Trends*, February 2004, based on 2000 time use survey

ONS published a second full HHSA in 2016, using both time use data and a range of survey and administrative data to estimate output.⁹ 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.¹⁰ 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

⁹ 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).

¹⁰ <https://www.ons.gov.uk/releases/householdsatelliteaccounts2011to2014>

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

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 earlier, the possibility of substitution between activities included in GDP and excluded from it has always existed. Since the 1950s there will have been an increase in the 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. Yet 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 rent for living in owner-occupied housing.¹¹ Scale was the key criterion cited for the existing production boundary convention, justifying the substantial imputation within GDP for services from owner-occupied housing. The same logic of substitutability and scale seems to suggest other categories of home production could argue for them being placed on the GDP side, or alternatively for removing imputed rent from GDP and putting it with other home-produced services in the HHSA.¹²

¹¹ 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>

¹² This is all the more significant given the impact of a tightly restricted supply of housing on house prices and therefore estimated total imputed rent and GDP in the UK context.

New issues

However, here I focus on newer kinds of non-SNA household production, rather than on the long-contested ones. In 2015, 80% of adults in the UK went online daily.¹³ 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' might also be increasing production activities by households for sale in the market, 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; examples include coding open source software, and creating user-generated content. I consider these 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.

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

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

¹³ ONS Internet Access Survey 2015

<http://www.ons.gov.uk/peoplepopulationandcommunity/householdcharacteristics/homeinternetandsocialmediausage/bulletins/internetaccesshouseholdsandindividuals/2015-08-06>

street shops, ask for items, and be served them by a retailer. Supermarkets have largely replaced the individual grocer or butcher, 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. 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 reflected currently. I consider this elsewhere (Coyle, in progress).

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).

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

The 'sharing' economy

A second set of household activities involving home produced but (often) marketed activities is sometimes described as the 'sharing economy'.¹⁵ In Table 3 these clearly sit in the final column (F) if non-marketed, and in the first column (A) if sold in the market. The challenges are practical rather than conceptual in terms of the 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.

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, 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 sector, the revenues of both the platforms (businesses such as Lyft and Airbnb) and the individual participants (drivers, hosts) need to be collected. So too the incomes earned by individuals, expenditure by consumers on these services, and also 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 'under the table' transactions. Again, these digital business models may have implications for price indices, a question I explore elsewhere.

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 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 HESA categories. However, 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

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 key, of course.

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

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, at present owner occupied housing is the only household asset to feature in national account statistics, in the form of the imputed rent 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). 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 is not yet clear. It may still be small, although 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). Even if hobbyists selling their products on a platform such as Etsy is very small relative to the scale of retailing in the economy, the fact that many people are engaging in some economic activity enabled by these new platforms is contributing to the blurring of another important boundary in the national accounts framework, as alluded to by Vanoli (2005): the clear distinction between 'firms' that organise employment in marketed economic activities, and non-productive consumers.

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 monetize 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). Table 6 gives examples.

As with household production for own-use, the time spent on these activities and its valuation should be accounted for. 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).

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 online material	Wikipedia; blogs	Purchased 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, commercialized as the markets grow	Von Hippel's (2017) surveys suggest it is extensive

There is also a significant question as to whether household provision of these unpaid digital activities 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). 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).

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 indeed, but it is difficult or impossible to assign them to a national territory.

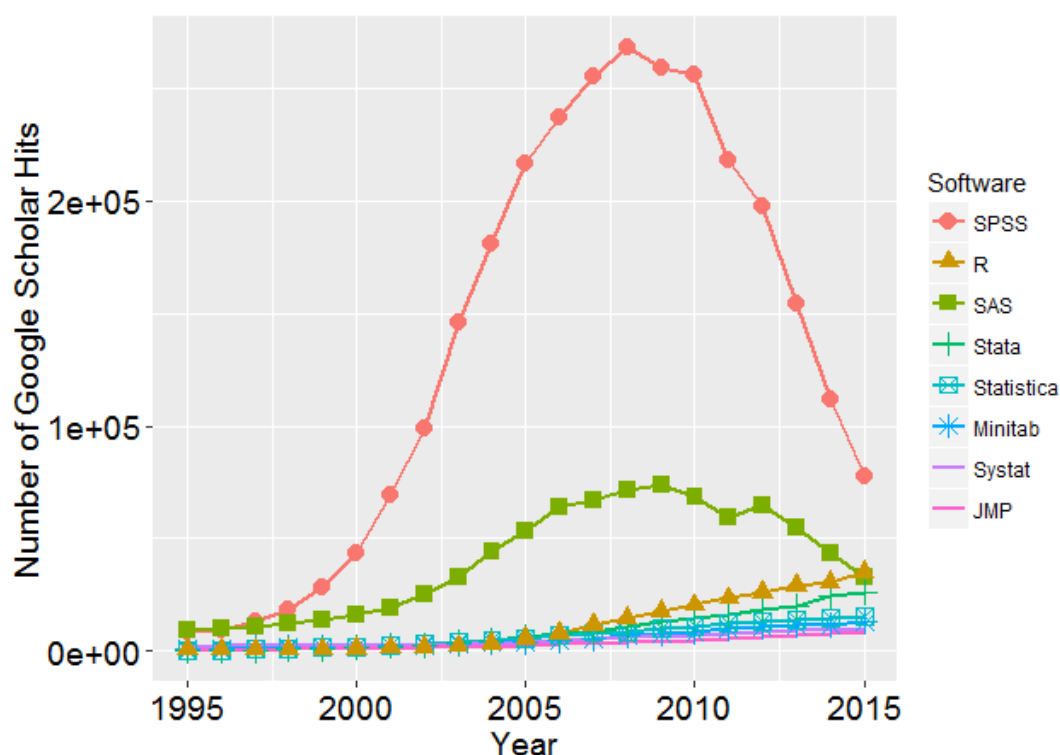
If they are determined to be own-account production of goods, however, in principle the question is whether they are now of sufficient scale to merit inclusion in GDP as it is currently defined. This seems a prohibitively complex challenge, given the difficulties of measurement and valuation. However, the extent to which these digital products are substituting for marketed products, the scale is relevant 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 is ample anecdotal evidence of for instance the rapidly growing use of open source software, including by large companies such as Walmart and Netflix.¹⁷ The cost savings businesses can make by switching to open source software are significant.¹⁸ 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) point to possible substitution (Figure 2).

¹⁷ <https://www.linux.com/news/enterprise-open-source-programs-flourish-tech-and-elsewhere>

¹⁸ <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 R, 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 consumption can readily switch between the marketed and non-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 HHSA. 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 (imputed rent) and other household production of services for own use (darker shaded) are considered equivalent. Either both could be included in GDP, via an imputation; or both could be excluded. There does not seem to be a strong reason apart from convention to continue the differential treatment, given the scale of other non-housing own-use services in the HHSA.

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 more important point, at least in the context of the productivity puzzle, 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 consumers 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 and means it would be useful to have a better understanding of the scale of the voluntary digital production.

Practical issues

The 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 of additional household data in the time use survey to understand the labour inputs used to produce these digital intangible goods and services. 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. 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.¹⁹ 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.

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

¹⁹ <http://www.digitaldayresearch.co.uk/media/1083/digital-day-2016-chart-deck-adults-aged-16plusin-the-uk.pdf>

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.²⁰ Collecting data on all purchases of items by households (currently counted as final goods in GDP) for use as intermediate products in home production and distinguishing these from normal household consumption expenditure seems an impossible task. It is probably small enough in scale to ignore – in contrast to household purchases of significant capital assets such as cars or computers.

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.

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 consumer 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

²⁰ An aggregate measure that does not deduct intermediate goods is Gross Output, now regularly published for the US by the BEA. See Skousen (1990).

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.

Conclusion

I argue, in contrast to some other recent research, that ‘mismeasurement’ due to digital technologies may be making significant contribution to the observed marked slowdown in productivity growth since around 2008. 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 (as 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 rapidly.

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.”

Another way of stating this is that some part of the impressive productivity growth recorded in the United States 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.

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