Digital Business Models and GDP

Diane Coyle
(Bennett Professor of Public Policy, University of Cambridge)

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In considering the impact of digitalisation on the measurement of GDP and productivity, a relatively unexplored issue is the lack of invariance of measured GDP (nominal as well as real) to new digitally-enabled business models. In general, information and communication technologies imply organisational change may be desirable. The rapid spread of smartphones and pervasive mobile internet connectivity since late 2007 in particular have led to dramatic business model innovations. Yet much of the literature on the measurement implications of new technologies has overlooked these, focusing instead on product innovations and their implications for the calculation of deflators. In addition to affecting the aggregate output measures, new business models blur existing statistical boundaries such as industry classifications, and the manufacturing/services distinction.

JEL codes: E01, L20, C82

Introduction

The structure of the economy changes constantly, and sometimes significantly. In general economists have not paid much attention to the implications of some such changes (for example the trend toward paid employment for women in the second half of the 20th century, or the development of cross-border production chains since the 1980s) in considering the measurement of GDP growth and productivity statistics. The assumption has been that the statistics as currently defined have continued to do a good enough job of tracking the macroeconomy. Digital transformation is now prompting a considerable amount of research into economic measurement, however. This is partly because the scale and scope of the consequences of the technology are becoming all too apparent (even to economists), and partly because of the question as to what part measurement issues might play (or not) in accounting for the ‘productivity puzzle’ in the OECD economies post-2008. Research on this question to date has included exploration of: the construction of the price indices used to deflate nominal GDP figures (see for example Reinsdorf & Schreyer 2017, Abdirahman et al 2017, Redding 2018); technology-related movements of activity across the production boundary (Coyle 2017); and the valuation of free goods and the boundary between GDP-relevant output and consumer surplus (Byrne & Corrado 2017, Brynjolfsson et al 2018).

This paper considers another route by which digital change might be affecting the measurement of GDP: whether nominal GDP may not be invariant to new business models. In a counterfactual world of no digital transformation, could measured nominal and therefore real GDP be higher than shown by current statistics? Furthermore, the new business models will certainly affect the allocation of activity to different sectors or categories.

After describing the context of the measurement debate to date, I discuss a number of business model innovations not as widely addressed in the recent literature:

- Substitution between advertising- and subscription-funded online services
- E-commerce
- Digital multi-sided platforms
- Cloud computing
- Contract (or ‘factoryless’) manufacturing
- ‘Servitisation’ of manufacturing

The implications for the calculation of growth and productivity, and for the collection of statistics, are considered.

Context: the productivity puzzle

There is a large and ever-expanding literature addressing the possible explanations for the productivity puzzle in OECD countries since the mid-2000s. As in any good mystery, there are numerous potential culprits. One of these is the possibility that measurement issues are playing a part, given the obvious scale and scope of digital change (Bean 2016). Among national accountants there is scepticism that the measurement problem poses any fundamental challenge to the framework of the System of National Accounts. On the contrary, a number of authors argue that the conceptual framework remains appropriate but there may be some specific challenges, particularly with regard to the deflators applied to nominal GDP and to the recording of cross-border transactions (see Ahmad and Schreyer 2016, Ahmad, Ribarsky and Reinsdorf 2017).

With regard to deflators, there are now a number of papers considering the implications of the appearance of improved and new goods in several forms such as: the digitisation of physical goods such as CDs or books; the availability of free digital goods; improvements in quality in goods such as ICT equipment; and increases in variety. New and improved goods are of course a classic problem in the construction of price indices. It led Zvi Griliches (1961) to champion hedonic adjustment of prices, in considering large quality changes in automobiles. The 1996 Boskin Commission Report was a milestone in prompting widespread recognition that for this among other reasons the consumer price index had a substantial upward bias. Subsequently statistical offices have adopted the Commission's recommendations, at least in principle. For example, they aim to include new outlets in data collection, to introduce new goods into the price index faster, and in addition carry out some limited hedonic adjustment. The price index challenge seems newly significant because of the rapid spread of digitised and usually much lower-priced versions of physical goods, the availability of lower-priced options for travel or other services through online platforms, and the substitution by consumers from physical products to free apps on smartphones since 2008 – for example, cameras, diaries, voice recorders, maps, calculators, address books and so on (Varian 2016).

One practical issue for statistical agencies has been keeping their data collection up to date, for instance ensuring that prices at online retailers are included in their samples. There is also a question similar to that raised by Griliches in the case of generic as opposed to branded pharmaceutical products: he noted that the practice was to treat a generic product as a new good rather than a lower priced version of an identical good. Is a camera in a smartphone combined with an app really a free camera plus film developing, in which case the price index for cameras and film processing would substantially lower than currently stated?

There have recently been attempts to quantify the resulting potential upward bias in price deflators. Reinsdorf and Schreyer (2017) make what they describe as 'worst case' assumptions to estimate a maximum upward bias of 0.4 percentage points in the CPI (and they argue the bias has reduced since 2008). Similarly, Byrne et al (2016) estimated a modest bias resulting from failure to fully hedonically adjust the prices of ICT equipment and services, but again found the incremental bias was lower in the post-2008 years. Abdirahman et al (2017) found that adding in broadband services to the deflators for telecommunications services – the late addition of a new good – reduced the product deflator by 35% after five years compared to the previous almost flat index, while a unit value index for broadband data services (that is, assuming an online message is equivalent to a free text message) showed a 90% decline.[1] Redding (2018) suggested there is an additional bias in standard price indices from the omission of increasing variety, analogous to outlet substitution bias.

There are some complexities in calculating price indices that at least partly offset the upward biases. For example, free apps are bundled into a smartphone the consumer pays for, either directly or through a service contract. 'Free' online goods of other kinds are paid for through higher prices for advertised products than in the counterfactual world. It is not clear what difference taking into account these effects on price indices would ultimately be. Groschen et al (2017) argue that the present difficulties in calculating price deflators are not substantially more challenging now than in the past. On the whole, these authors conclude there may be limited mismeasurement, particularly due to classic deflator problems, but not enough to help explain the productivity puzzle.

In addition, this literature tends to argue that those suspecting a more profound impact of digital technology on measurement are confusing the measurement of economic activity with the measurement of economic welfare. Ahmad and Schreyer

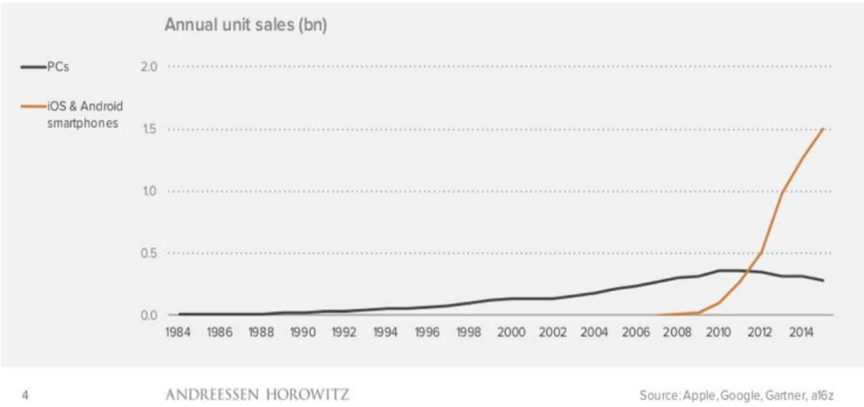
[1] although much of the impact of this would be to re-arrange the real output estimates for different sectors as broadband services are an intermediate input for other industries.

(2016) emphasise this distinction: "It is clear that consumer valuation should not attempt to measure total consumer welfare arising from the use of free digital products, just as the value of traditional market products is not a measure of consumer welfare. Measures of the total value of consumer welfare such as consumer surplus are at odds with the conceptual basis of measuring GDP and income…. [M]easuring production and income is a different objective from measuring welfare."

This is somewhat disingenuous: price indices are conceptually intended to hold consumer utility constant, so real GDP is in fact inherently constructed as an implicit welfare measure. Furthermore, hedonic adjustment for quality change attributes some increase in consumer surplus to specific product characteristics (such as faster processors or built-in camera), and this is a somewhat arbitrary attribution in practice dependent partly on data availability for certain characteristics. Yet the claim is often made that GDP does not aim to measure change in consumer surplus, and that there are consumer welfare gains from digitalisation that, albeit important, should not be incorporated in the national accounts in any way. Still, as GDP is clearly an inadequate economic welfare measure, there is a growing body of work aiming to estimate the welfare benefits of digital innovations directly. For example, Corrado (2018) and Bryjolfsson et al (2017) argue their direct estimates could be added to currently-defined GDP figures. Calculation of consumer surplus is in any case assumes no change in the mix of expenditures in the economy and is therefore likely to understate the welfare gains addressed by the counterfactual question of what would social welfare have been absent the technological change (Crafts 2004; Leunig 2010).

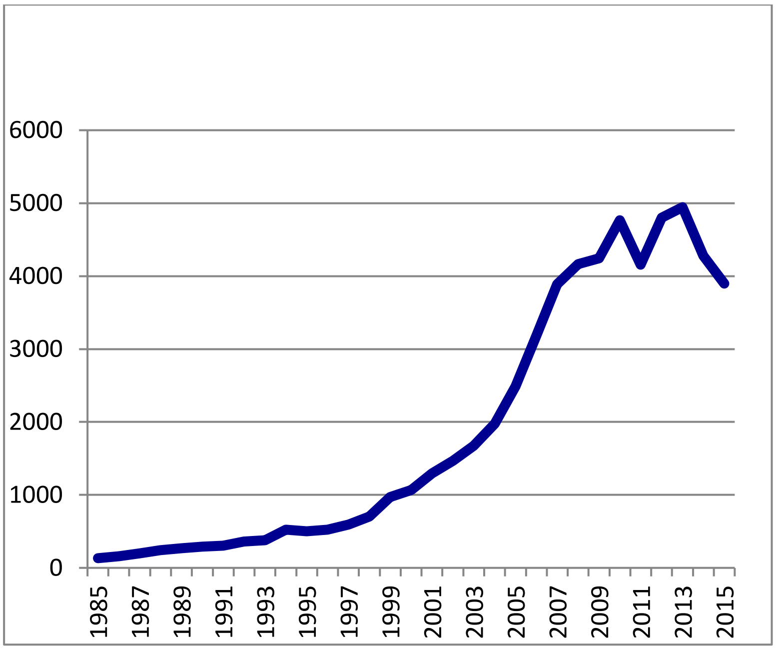
In any case, whether it is a deflators issue or a wider question of the GDP/welfare boundary, the debate is far from resolved. Those who continue to think measurement issues likely to be causing a downward bias in GDP as measured point to the rapid spread of smartphones and always-on mobile internet connectivity since late 2007, and to the extensive substitution of free apps for paid-for goods such as cameras (see Figures 1 and 2 for an illustration). Everyday observation indicates how extensively these innovations are being used both in consumption and in business, while some new business models such as digital matching platforms are very visible.

Figure 1: Annual smartphone sales



Source: Andreessen Horowitz. Permission granted by Benedict Evans

Figure 2: UK retail sales of all AV equipment, 2015 £000CHK



Source: ONS

This paper takes a different tack and argues that the measurement of GDP is not invariant to the business model choices firms are making as they adopt and use digital technologies. In other words, in the counterfactual world of no digital change, both nominal and real GDP would be higher, and sector allocations would differ. Estimating the scale of any effect would require additional data collection. However, as the business model innovations relate to the diffusion of digital technology and in particular pervasive mobile and fixed broadband connectivity, they could potentially contribute somewhat to explaining the productivity slowdown since the mid-2000s and especially since 2007.

Digitalisation will lead to business model changes, as the technology reduces the transactions costs Coase (1937) and the subsequent industrial organisation literature observed to determine the structure of the firm and its contractual relationships. Digital technologies reduce the costs of communication and co-ordination. (See Garicano 2000, and Garicano & Rossi-Hansberg, 2015, for an overview.) They are also likely to change the relative influence of different information asymmetries. For example, the extent to which effort is observable may determine the choice between a conventional integrated services firm and a digital platform (Hagiu and Wright, 2015). I return in the final discussion section to some reflections on the digitally-driven reorganisation of production, and the implications for economic measurement

Advertising funded ‘free’ online services

One of the most widely discussed new business models is the provision of extensive advertising-funded free online services. This is an old issue at a new scale, as it also applies to advertising-funded free-to-air television. Comparable to TV broadcasts, some online services are funded through advertising, while others offer users a choice between paying a subscription and viewing advertisements. The co-existence of the two options makes it abundantly clear that ‘free’ goods online are not free. Apart from the fact that advertisers will have to cover their costs and may do so through consumer price increases, there is also a direct time and attention cost to consumers. However, the ‘free’ versions of the service do not get counted directly in GDP whereas subscription versions do. Currently, the national accounts treat advertising as a marketing expense for the goods being advertised; no value to the consumer of the free entertainment is counted. As Nakamura and Soloveichik (2017) note, this treatment led to a decline in recorded consumer entertainment expenditure during the 1950s as people switched from going to the cinema to watching TV.

Similarly with substituting from paid for products such as newspapers and CDs to advertising funded 'free' online alternatives.

Ahmad et al (2017) consider the advertising-only revenues of media industries as an indicator of the scale of this issue, and find that it ranges up to 1.3% of GDP for the US, where adding back the substituted expenditures would have contributed an extra 0.07 percentage points to economic growth on average over the period 2009-2013. In only a few OECD countries (including the US) do digital providers capture a significant part of this advertising revenue.

Nakamura and Soloveichik suggest the attention cost of viewing advertising could be imputed in constructing total GDP. They propose imputing a consumer payment for the entertainment paid for by the advertiser. This removes the boundary problem of consumer substitution from paid-for to 'free' entertainment affecting measured real output. However, taking into account total advertising spending and the substitution from other categories to online, they found that treating the provision of free, advertising-funded online media in this way adds only a small increment to real GDP for the countries they consider, just 0.0065% a year on US nominal GDP growth for online free entertainment.

Consumers can and do easily substitute between advertising-funded versions of a service and subscription-funded versions. The pattern varies by category. For example, search and social media are universally free, and hence advertising supported. The norm that other online services such as newspapers and music should be free was established in the early days of the spread of the internet. This is starting to change. After the shock effect of Napster early in the digital era, the music industry has steadily moved to subscription funding. For example, in the UK in 2017, of total digital revenues of $651.5m, $500.6m came from streaming rather than downloads, and just $19.7m of that consisted of advertising supported streams. In Europe, 85% of streaming revenues consisted of paid subscriptions.[2] Some other online content providers such as newspapers have found their ability to continue in business undermined by the 'free' model, as their share of the total advertising

[2] Global Music Industry Report 2018.

market has plummeted, and are increasingly experimenting with forms of charging, either compulsory or voluntary subscription, while regulatory concern about the advertising-supported model has increased dramatically.

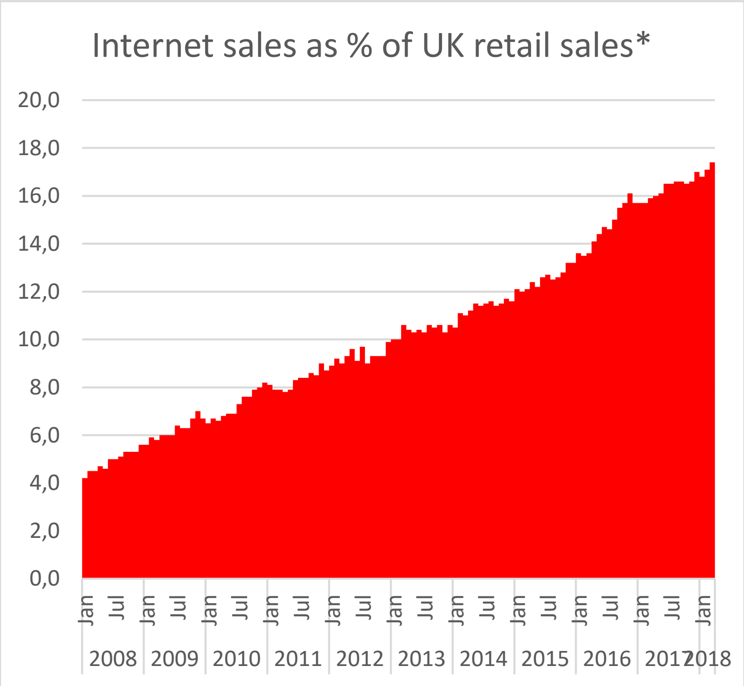
Ideally, GDP would be invariant to consumer substitutions from paid-for to 'free' versions of the same product category. But combined with this shifting market context, the small scale of the estimates of how much difference inclusion of ad-funded free digital media might make to GDP seems to be an encouraging conclusion, as they suggest the issue can safely be ignored. The emerging consensus seems to be that there is no need to change any national accounts definitions but it would be desirable to try to measure the consumer welfare benefits of free digital goods (see for example IMF 2018).

However, this does not seem entirely satisfactory given the scale of use of the free digital services. Billions of people globally every day use search, social media, free email, video and music services and so on, and the providers are among the biggest businesses in the world. An alternative approach could be to treat free digital goods in a manner parallel to other 'free' goods in the national accounts, namely government-provided, tax-funded public services and non-profit services. Online services have the economic characteristics of public goods, being non-rival, and of natural monopolies, as there are substantial upfront costs and low marginal costs. So one can as a thought experiment imagine that Google's and Facebook's core services were nationalised and provided by the government instead (setting aside the cross-border complications). Valuing them at the cost of provision, as traditionally done for government expenditures, would translate what is currently treated as a business expense (therefore reducing nominal GDP) into an increment to GDP. This approach is not obviously better than the imputation approach described above, but nevertheless demonstrates that the conceptual and statistical treatment of this important aspect of economic life needs further consideration.

E-commerce and online services

In many countries there has been a strong trend toward online shopping, banking and other financial services, travel agency and so on. For instance, in the UK, online retail sales have reached about 20% of total retail sales (Figure 3). Surprisingly, the proportion has reached just 10% in the United States (Figure 4).[3]

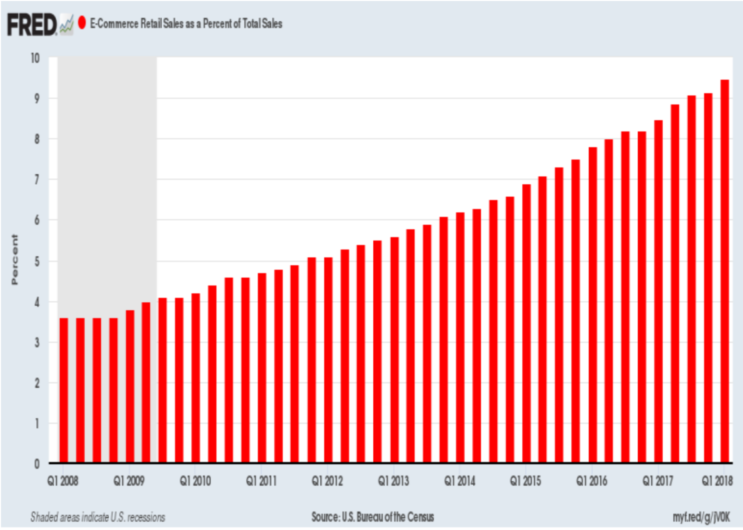
Figure 3



Source: ONS

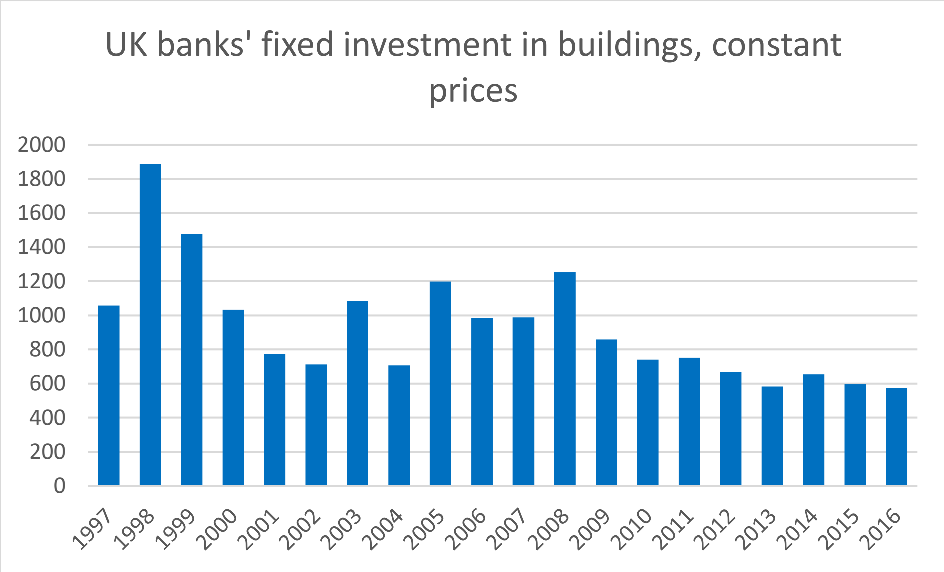
Figure 4: US e-commerce as a % of total retail sales

[3] Evans, Murray and Schmalansee (2017) raise some questions about the Commerce Department's classification of e-commerce sales by some large retailers with a physical store network.



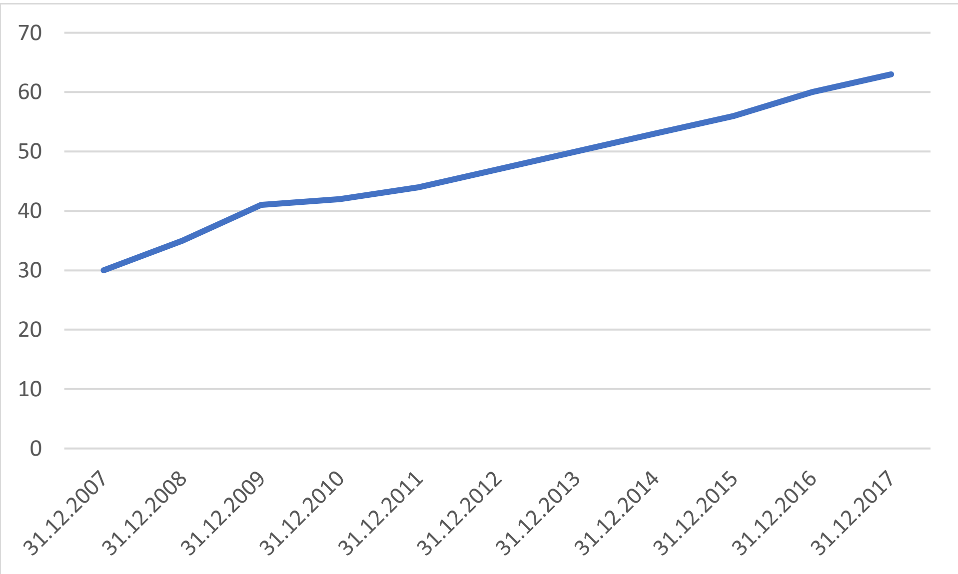
The trend to online consumer activity has several implications including the growth in the logistics and courier sectors, as traditional retail has declined. I have written elsewhere about the way such shifts, along with the use of some digital platforms (see below) are moving activity across the SNA production boundary (Coyle 2017). One largely overlooked consequence is the decline in fixed investment in buildings by sectors such as retail, travel agency, estate agency and banking. One can think of it as an increase in the productivity of bricks in supplying consumer services. This transition is striking in some sectors. In UK banking, for example, the number of branch closures and decline in buildings investment by the sector is quite substantial (Figure 5). About two-thirds of UK adults use online banking services (Figure 6), and the UK has adopted cash-free means of payments rapidly, reducing even demand for ATMs. If the UK's retail and banking sectors had invested as much in buildings in 2016 as they did 10 years earlier, total fixed investment in buildings would have been about 0.5% higher, implying a modest effect on total investment and GDP compared to the counterfactual world.

Figure 5



Source: ONS

Figure 6 Proportion of all UK adults using internet banking



Source: ONS

Digital platforms

Digital platforms matching consumers with suppliers (including those referred to as the ‘sharing’ or ‘collaborative’ economy) have grown to take an important share of certain markets such as travel and accommodation. They have some of the characteristics of marketplaces or exchanges, rather than slotting into a traditional linear value chain as conventional retailers or wholesalers. While usually starting by providing matching for one kind of service they often take advantage of the user groups they have built up on one side or other of the platform to extend into other services, in the strategy known as 'envelopment' (Coyle, 2015). Thus for example a transportation service may expand into food delivery (Uber and Uber Eats) or an accommodation service into sports and travel guides (Airbnb). Although some of these platforms often grew out of a particular non-profit philosophy, the decision to operate as a platform is a business model choice. There are many examples of organisations operating both models, such Amazon establishing Amazon Marketplace or Accor acquiring Onefinestay. Some big platforms also operate as a platform for smaller platforms, such as Stripe offering payment services for a wide range of other platforms or Airbnb offering insurance and escrow services for other accommodation platforms (Coyle, in progress).

Some of the statistical challenges posed by such platforms have been discussed elsewhere (ONS, 2017). For example, there is a need to ensure the prices available to consumers through platform substitutes are captured in price indices, to avoid something similar to outlet substitution bias. In general some statistical agencies are not capturing lower transport and accommodation costs in consumer price indices.

However, the implications for deflators are not the only issue. The digital platforms are in addition leading to a substitution away from traditional retail sales (for example, travel agency on the high street) to intermediation margins (such as the fee charged by Airbnb). The revenues earned by home-owners via the platform may be less than the retail sales they have displaced (due to lower prices per night of occupancy – although demand might expand too). Data gathering may simply miss the small-scale production activities of households, such as providing accommodation or pieces of work that would not otherwise be occurring (some of the platform-enabled supply and demand will be substitution from more conventional versions but some will represent an expansion of the market). So while in principle the activities enabled by the platforms may largely fit into the SNA framework, there is a challenge in data collection, albeit one being overcome through co-operation with the big platforms. Additional complexities stem from the cross-border operation and allocation of IP and revenues by large platforms. Their net revenue may well be booked in their country of domicile and some of their profits there or elsewhere. Not all countries have sufficiently low thresholds for recording the small transactions that characterise online cross-border sales (IMF 2018).

The envelopment strategy has implications for the sector classification of platforms and other big digital businesses. Amazon is clearly a retailer (G47.91) but also a major provider of cloud computing services (J62 or 63), a producer and distributor of entertainment content competing with broadcasters (J59), and a 'factoryless' manufacturer of own-brand goods such as clothing (see below), which could in theory be recorded as either manufacturing or distribution. Uber provides both short car rides and food delivery, and is planning to expand into autonomous vehicle services. A number of digital platforms consider themselves to be technology businesses rather than providing specific consumer services. While the same classification challenges arose in the case of industrial conglomerates in the past, they have returned at scale with the digital conglomerates. Given the lack of granularity for services at all in the SIC classification, there is clearly a need to consider the different approaches to classification taken by both the businesses themselves and by statistical offices.

The wider issue is whether the construct of a linear value chain within vertical sector classifications is a suitable means of classifying businesses which refer to their 'ecosystems' or 'networks'. I return to this below.

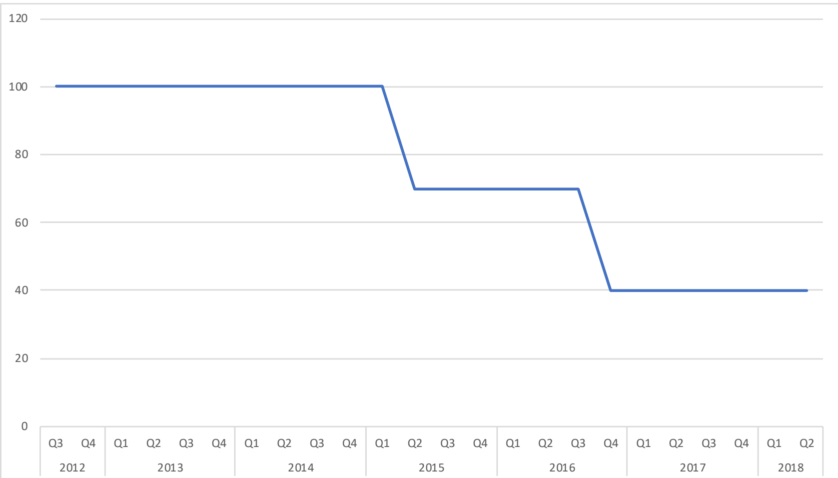
Cloud computing

The adoption of cloud computing services in place of fixed investment in computer and communications hardware and the development of own-account software is a rapidly growing business process improvement. Cloud computing refers to a range of software and computing services provided by (mainly) large vendors from their data centres. Their ability to undertake the fixed investment with the benefit of large economies of scale and specialised expertise enables businesses and consumers to use the services without purchasing their own equipment and/or software, and requiring less in-house expertise. The users get better computing services at lower cost.

In its modern form, cloud computing can be dated to the 1999 launch of Salesforce, offering software-as-a-service, while Amazon Web Services launched in 2006. In the UK and elsewhere the market leaders are currently Amazon Web Services (AWS), Microsoft and IBM. The use of cloud computing globally has increased rapidly during the past five years according to industry data, and one fifth of UK businesses used these services in 2015.[4]

Byrne et al. (2017) report that as the use of cloud computing increased rapidly in the United States, the price of using cloud services decreased significantly. They constructed a new dataset on quarterly prices of cloud services for in the US between 2009 and 2016. Coyle & Nguyen (2018) similarly construct prices for cloud services in the UK showing significant price declines in the services offered. Figures 7 and 8 give examples of typical price profiles for different products; all show a decline over time, and particularly when there is new entry.

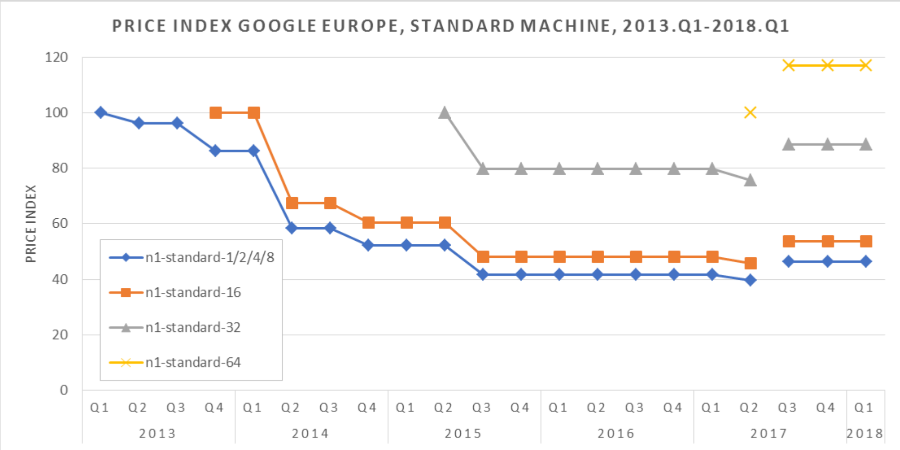
Figure 7 AWS quarterly price index for S3, 1 GB / month (Glacier storage). Q3-2012 = 100. 2012-2018.



Source: AWS press releases and price lists

Figure 8 Price index Google, Europe: Standard machine, 2013.Q1 – 2018.Q1.

[4] https://www.statista.com/statistics/510350/worldwide-public-cloud-computing/ & ONS.



Source: Calculations based on GCP prices on website.

The increasing use of cloud computing by businesses will have direct effects on their measured investment, as less physical investment in ICT equipment such as servers and own-account software development by the firm itself is needed. This issue is highlighted by a statement on the website of the Google Cloud Platform (GCP): "*In cloud computing, the capital investment in building and maintaining data centers is replaced by consuming IT resources as an elastic, utility-like service from a cloud "provider."*" [5]

Hence some 'investment' becomes 'intermediate consumption'. Since gross fixed capital formation (GFCF) is a component of the expenditure measure of GDP there are potential implications for measurement as compared to the no-cloud counterfactual world. Domestic businesses will reduce their investment in hardware as they switch to using the cloud, and they will also substitute cloud services for software purchases or development. Nevertheless, they are still using the capital services provided by such equipment and software. Furthermore, the price paid by the businesses using these cloud services will likely be substantially lower than the cost to them of own-provision of the required computer services, and the quality of the services (access to the most up-to-date versions for instance, and greater flexibility) will be higher. Even if the purchase of cloud services were correctly to be considered as an intermediate purchase rather than use of capital services, the failure to double deflate (and quality adjust correctly) would lead to an underestimate of 'true' total factor productivity.

[5] https://cloud.google.com/what-is-cloud-computing/. Accessed on 1. March 2018.

Cloud providers may serve UK customers from data centres overseas or in the UK; in the latter case, while they will purchase the IT equipment, which will form part of their GFCF and should in principle be captured, this will still be imported. As large purchasers, they will pay less for the capital equipment, however; indeed, some major providers are reported to buy unbranded components and customise their own IT hardware.[6] If the former, equipment previously imported by UK businesses will instead be imported to wherever the data centre is located (eg Belgium).

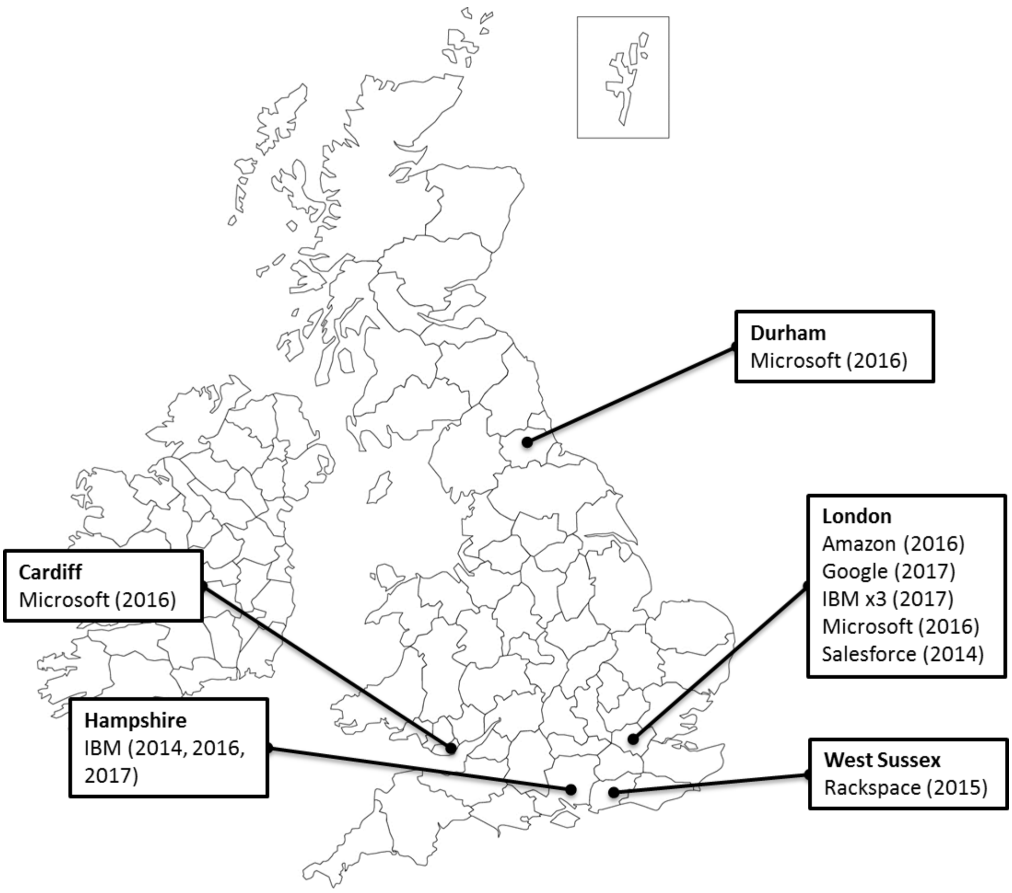
Overall, the likely effect is that companies using cloud services will spend less on a more flexible and higher quality capital service, with less need for in-house know-how and the scope to embrace new possibilities (such as machine learning or AI in the cloud). These customers will be able to achieve productivity gains through process innovation. Yet there will if anything be a reduction in measured real GDP with the switch from fixed investment to purchase of an intermediate input by businesses, not fully offset by increased (domestic) investment by the cloud providers.

However, to unpick these effects, quantity indicators are required. It is not even possible to construct a single 'cloud' price index without expenditure shares for the different types of service (storage, software, services…). Industry sources do not have a consensus volume measure to set prices. One model is number of core hours used; the pricing and investment model in this case would be similar to the electricity industry, where pricing is used to manage demand for given capacity but as demand grows, decisions to undertake new investment in capacity are taken – either additional servers or new data centres. Successive new investments in datacentres have been undertaken in the UK since 2014 (Figure 9).[7]

Figure 9 Map of UK datacentres by main cloud providers

[6] In 2017 GCFC accounted for approximately 17% of UK's GDP, in volume terms (ONS, 2017). https://www.ons.gov.uk/economy/grossdomesticproductgdp/articles/aninternationalcomparisonofgrossfixedcapitalformation/2017-11-02

[7] Microsoft is currently trialling a new underwater datacentre off the Orkneys, installed June 2018.



Source: Coyle & Nguyen (2018)

The business and computing press, as well as analysts' figures for cloud revenues and growth, indicate that business use of cloud computing services has been growing rapidly although the market is small relative to total business investment. These businesses are substituting cloud purchases recorded as operating expenditure for purchases of hardware and some software recorded as GFCF, paying a lower price for a higher quality of capital service. If there is some "vanished capital" compared to the counterfactual no-cloud world, the substitution will affect calculations of total factor productivity. In the usual framework, following Brynjolfsson, Rock & Syverson (2017) for example,

$$Y + zI = f(A, K, L, N)$$

where Y is output, I is cloud capital with price z, A is total factor productivity, K is other capital, L labour and N unmeasured intangible capital, with rental prices r, w and h respectively. The measured Solow residual will be

S' = dY/y – (rK/Y * dK/K) – (wL/y * dL/L)

.which will differ from the 'true' residual by the term

(zI/Y * dI/I) – (hN/Y * dN/N)

This will be negative – that is, measured TFP growth will understate the 'true' rate – if the growth rate of investment in cloud capital (weighted by its output share) is greater than the (weighted) growth rate of the stock of the capital services, which is likely to be the case early in the adoption of the new cloud model. Alternatively, in the counterfactual world of no cloud model, there would be no measurement wedge of this kind (setting aside all the other measurement issues including absence of double deflation, intangible investment etc).

It clearly would be desirable for statistical offices to collect additional data, on volume of usage as well as pricing for specific products, on hardware and built capital investment by the cloud providers. Although there will be a limit to the data traffic implied by use of cloud services (and hence innovation in 'edge' computing i.e. increasing processing capabilities in handsets or remote devices), there is every indication that cloud services are a large, growing market and now a permanent capital services option for businesses.

Factoryless goods production and servitisation

Two final, related business model phenomena also with potentially large measurement implications are 'factoryless manufacturing' and 'servitisation' in manufacturing.

The former, which is particularly pronounced in some sectors such as pharmaceuticals, consumer electronics and apparel, involves firms that design and innovate, and retain IP, and also retail the products, but contract out the actual production. High profile examples include Apple, which does not manufacture hardware, Nike, which does not make shoes or clothing, and Dyson, which does not manufacture consumer white goods. Such companies may not be classified statistically as manufacturers, but rather as distributors, and classification practice will vary between countries.

The scale of factoryless goods production (FGP) is not small, although as with the other instances considered here there is a lack of key underlying data. One study for the US finds that reclassifying FGP establishments could shift between 0.4 to 1.9 million workers from wholesale trade to manufacturing (Bernard & Fort, 2013, 2017), which is equivalent to 3-14% of total manufacturing employment in 2007.[8] Factoryless manufacturing also seems to be the prevailing model manufacturing of pharmaceuticals and apparel in the OECD economies (Bernard & Fort, 2015). Bayard et al. (2015) show that reclassifying wholesale traders engaged in FGP (and product design) to manufacturing would raise manufacturing value-added between 5-20% in 2002 and 2007. The contracted manufacturer may be domestic or offshore.

Servitisation consists of manufacturers who sell high-value after-sales services along with their products (which they might or might not manufacture themselves). Neely et al (2009) estimated that around 30% of firms classified in manufacturing globally offered services alongside their products. The scale may be greater to the extent that some firms which do some manufacturing are classified in service SIC codes, although most are likely to be classified in manufacturing. Again, the scale of the phenomenon may be large. High profile manufacturers deriving a substantial portion of their revenues and profits from services include Phillips, Rolls Royce, Caterpillar, and ABB for example.

If the way such firms combine inputs to produce output in their production function differs from the usual assumptions, this can have implications for the way we measure value-added and productivity (Bernard & Fort, 2017). At the same time, factoryless manufacturers are often classified in official statistics as wholesale

[8] The study is based on the US Census of Wholesale Trade for 2002 and 2007.

traders or as part of other service sectors, rather than manufacturing. This has obvious implications for measuring the 'correct' sectoral composition an economy, particularly as policies are often directed towards 'manufacturing'. Finally, reclassification can have important implications for the composition of trade flows in terms of goods and services: contract manufacturers that use foreign contractors will record transactions as imports of manufacturing services, but not as goods imports, as would be the case with wholesale traders (Bayard, Byrne, & Smith, 2015).[9]

A further point is the statistical treatment of the IP owned by factoryless manufacturers, particularly when they contract to an offshore business for the manufacturing. The trade statistics do not record the intangible transaction; there will be zero priced data flows in the value chain. Needless to say, the imported goods are captured in trade statistics.

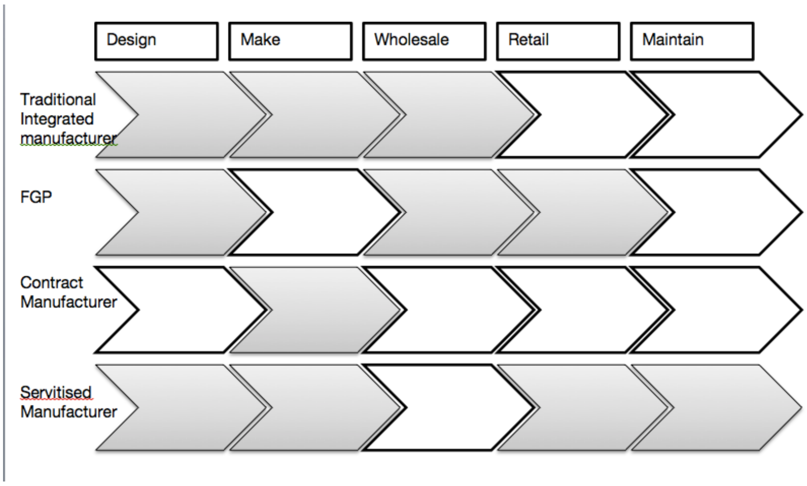
There is a large literature on the way firms have reconfigured production chains, nationally and internationally, in response to changes in information and communication technologies See Baldwin 2017 for an overview). This splitting up of value chains would surely not have occurred unless the firms so doing derived significant benefit; and yet this massive reorganisation of production is not revealed by current productivity statistics. Figure 10 illustrates the different parts of the value chain occupied by different types of firm. The business model choices clearly cut across the conventional categorisations. The SIC classifications are anyway not invariant to the value chains operating in different sectors of the economy. For example, 'construction' (Section F) excludes architecture and engineering (M71), and project management, which are high value-added activities but not vertically integrated; and includes relatively low value added maintenance and repair. On the other hand, 'motor vehicle manufacture' (C29) includes the high value added design and engineering phases, which are vertically integrated by the major manufacturers, but excludes lower valued-added repair and maintenance (G45) (Winch 2003). There is almost certainly a lack of consistency in the classification by different statistical offices of manufacturers making different business model choices about

[9] There are crucial differences between contract manufacturing and other global production arrangements such as merchanting, where the contractor provides the IP inputs and the principal is general defined as a wholesale trader (UNECE, 2015).

which parts of the value chain to occupy, and in any case a lack of clarity in policy debate about the manufacturing sector. Figure 11 illustrates the complexity of the firms' production and distribution decisions, and the unanswered questions this raises.

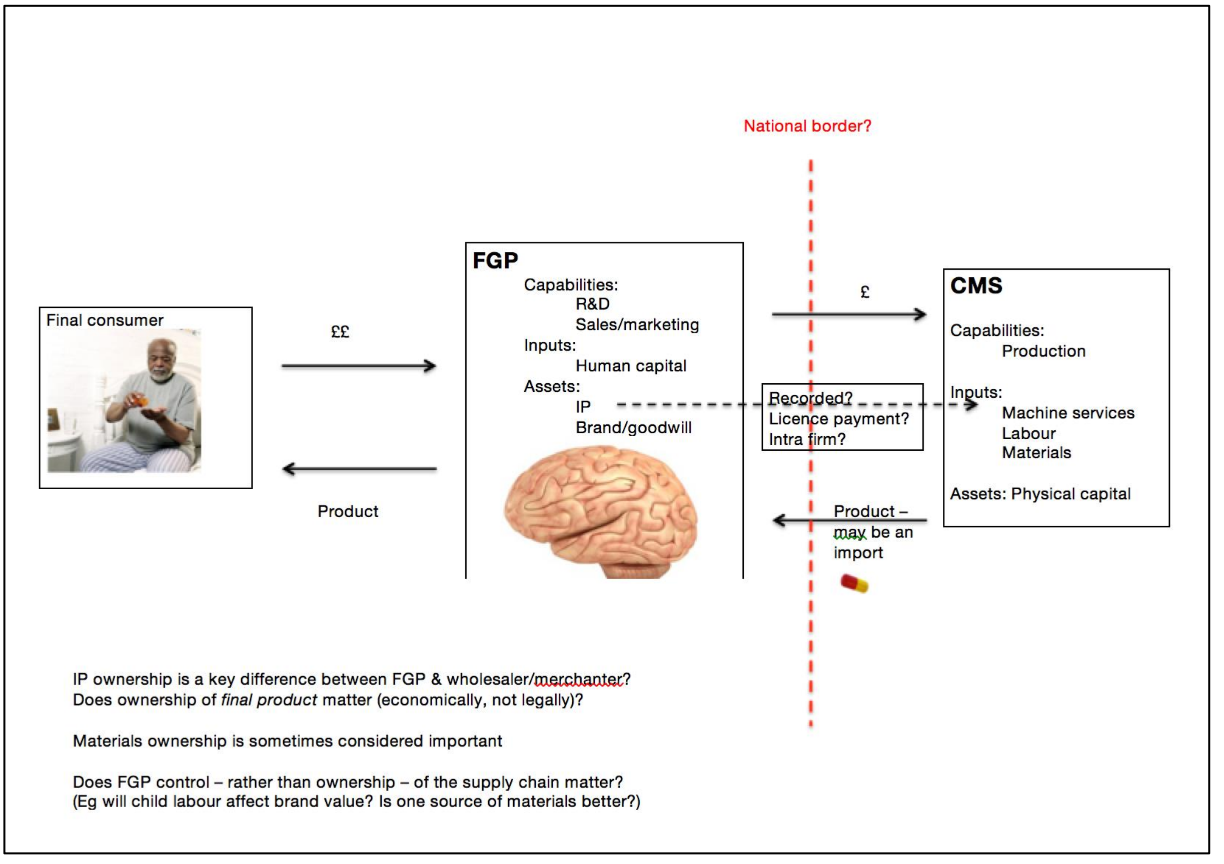
Some authors consider that the process of industrial reorganisation is continuing with the evolution of 'distributed manufacturing', a concept which involves a production network of providers of various inputs into the process of producing a combination of goods and services to serve specific end-user needs (Srai et al 2016). The contributory influences are the phenomena of additive manufacturing (enabling small scale and customised runs at dispersed locations) and the 'internet of things' as well as now-traditional outsourcing and offshoring choices, all enabled by digital connectivity and processing. This approach too does not fit the idea of a linear value chain, allocating value added to specific stages in clearly defined sectors, as embedded in the SNA.

Figure 10 Value chain choices in manufacturing



Source: Coyle & Nguyen

Figure11 Schema for Factoryless Goods Production



Source: Coyle & Nguyen

Discussion

This paper has argued that the measurement of GDP on its current definitions is not invariant to business model choices made by firms, which may also be affecting the classification of activities into different production sectors, and trade statistics. This is in addition to two aspects of the measurement debate considered widely elsewhere, namely appropriate price deflators for new goods and quality change at a time of rapid digital innovation; and the distinction between what should properly be counted in GDP and what should be considered as increments to economic welfare. This paper has discussed a number of business model changes that would reduce measured GDP, as compared with a no-digital counterfactual. Some of these probably have small effects. Although small, though, the effects will have accelerated from 2007/8 as smartphones and always-on internet have diffused. What's more, a range of small effects, combined with the range of effects on deflators, may add up to something not quite so small.

Two business model innovations may have quantitatively significant effects on measured GDP as compared with the counterfactual: the reduced physical investment in ICT equipment and software as many companies (in services and manufacturing) switch to the use of cloud computing services; and the long-established trends to so-called factoryless goods production and servitisation of manufacturing, as companies select different parts of the value chain in which to operate, in contrast to the standard section of a linear value chain occupied by conventional vertically integrated manufacturers. The move to the cloud in particular will potentially have a noticeable effect on GDP and productivity, as compared to the counterfactual world. It is complicated to assess the impact of changing manufacturing business models on the aggregate but one factor depressing measured GDP will be the zero priced transfer of IP to contract manufacturers by factoryless goods producers. The fact that the activities often cross international borders is a further difficulty. It is also likely that there are some surprising sector classifications in current practice, with some significant manufacturers classified into wholesaling.

One firm conclusion from this exploration is that additional data collection is needed, in particular:

- cloud computing providers – fixed investment, volume of usage (by product), data flows (including cross-border);
- gross domestic fixed capital formation in servers and software by other businesses (at sufficient granularity – not available in the UK);
- imports of server equipment and prices;
- values and quantities of IP, materials and goods transacted in manufacturing value chains, including cross-border;
- cross-border transactions by digital platforms;
- prices of services and products via digital platforms to be included in consumer price deflators.

This is a demanding list but absent the collection of new data it will not be possible to get reasonably reliable estimates of the scale of important phenomena in the digitalising economy. In addition, the SIC classifications need revisiting. There is insufficient granularity in services in general, and in those relevant to the phenomena of digitalisation discussed here in particular.

While the phemonena discussed here are not brand new, they have been accelerating during the past decade. At least some of them will have reduced GDP measured on current definitions as compared with the counterfactual non-digital world. The scale is at present impossible to ascertain.

However, that is perhaps not the most important statistical challenge they pose. An additional although necessarily more tentative conclusion is that business model choices in the digital economy are blurring some of the key concepts in the SNA framework:

- free online services are in effect public goods, some financed as club goods through subscriptions, others through a 'tax' in the form of attention and/or data. They are a 'diifficult' sector and could perhaps be treated via an imputation (like finance) or added to GDP (like government expenditure). While ignoring them may be tempting, it is a big phenomenon to deem irrelevant to economic measurement;
- platforms do not fit neatly into linear value chains, as they create value through network externalities and matching. Some also shift activity across the production boundary;
- businesses may choose to invest in computer hardware and software or purchase and use it as a service. In general, there is likely to be a continuing trend to buying services or renting assets rather than investing in capital goods or consumer durables – not just cloud services but potentially also autonomous vehicle fleets, 3D printing etc.;
- manufacturers may choose not to manufacture but to contract out their physical production, or to provide post-sale services. Firms are choosing varying parts of the value chain in ways that are playing havoc with sector classification. Cross-border transactions and the transfer of intangible assets pose particular challenges.

The general issue is the increased variety of companies' choices with regard to the organisation of production, in both services and manufacturing. This reflects the impact of digital technologies on transactions costs and hence choices about the boundary of the firm, which activities to integrate within the organisation and which to buy in, and contractual relationships. In service businesses the reduced cost of matching may incentivise a platform model, for example, as long as there are not significant spillovers between suppliers that would make a conventional 'linear' model more attractive. In manufacturing, firms will be more likely to focus on activities that play to their competitive advantage in production as the costs of co-ordination with other firms have fallen, reducing the advantage of traditional integration of activities. Whether or not measurement issues help 'explain' the productivity puzzle is one of the drivers of the current wave of research into digitalisation and economic statistics, but there may be a more important question about the growing mismatch between the existing statistical framework and the digitalised economy. When structural changes leading to such big changes in business and consumer behaviour are hard to spot in the principal economic statistics used by policymakers, it is a question worth asking.

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