Macroeconomics of the machines

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The effects of advances in technology are typically thought of as microeconomic in nature, affecting market structures and pricing behaviour. But evidence is mounting that these micro effects now aggregate to meaningful and lasting macroeconomic consequences, possibly explaining why our traditional macro models struggle to explain the ‘puzzles’ behind weak output growth, low productivity, muted wage increases and subdued inflation. This may require adjusting the theories that guide our economic analysis, including on monetary policy, public finance and development strategies.

Our primary findings

- **Growth is becoming increasingly difficult to measure in a digital economy, and likely underestimated by current methods.** Our manufacturing-focused concept of GDP does not include digital products’ consumer rent and also struggles to capture properly the effects of sharing and disintermediation, quality improvements and intangible capital. Depending on the methods used, annual growth rates are estimated to be up to almost 3/4ppt higher if adjusting for the digital economy.

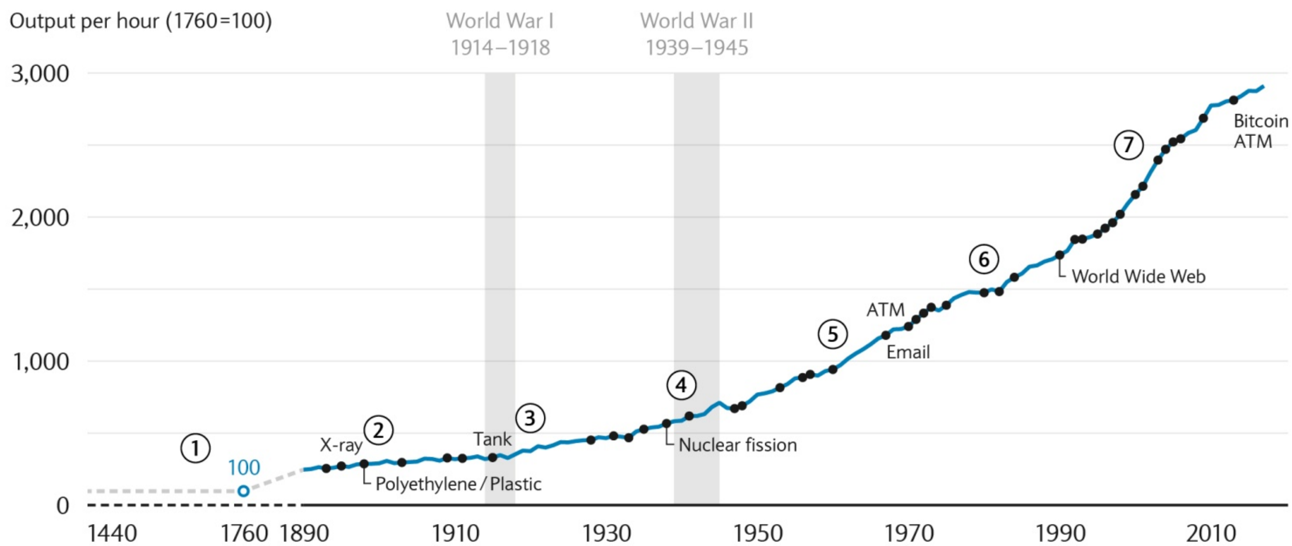
- **Inflation is likely lower than official estimates, and technology is affecting its underlying dynamics, in particular through wages developments.** Challenges in quality adjustments suggest that official inflation rates may at times be over-recorded by as much as 1%. Besides lowering inflation rates through improving quality, falling IT prices and intensified competition (e-commerce), technology is also affecting underlying inflation dynamics through the labour market (automation).

- **New technologies could turn globalisation on its head.** Advances in robotics and 3D printing could bring increased re-shoring, in part reversing the earlier creation of global value chains, and accelerate premature de-industrialisation. This could pose challenges for traditional development models and, thus, the ability of developing countries to climb the income catch-up ladder.

- **Policymakers will have to consider the implications:** First, policy analysis needs to expand beyond GDP when assessing societies’ progress and well-being. Moreover, the focus of economic policies may shift from efficiency towards distribution, as machines may bring abundance but not necessarily equity. For public finance, this may imply temporary and possibly permanent income support measures, but securing a tax base may be challenging. Central banks may need to adjust to a world where inflation can be less easily controlled within inflation targeting regimes.

FIGURE 1

From the printing press to the global internet, technology has evolved, and human societies with it



(1) 1890 and earlier

1440 Gutenberg Printing Press
1480 Sea astrolabe
1589 Mechanical knitting machine
1608 Telescope
1630 Slide rule
1765 Watt's steam engine
1790 Sewing machine
1816 Telegraph
1867 Dynamite
1879 Light bulb

(2) 1891–1910

1893 Diesel Engine
1895 X-ray
1898 Polyethylene / Plastic
1903 Gas turbine
1909 Television broadcast

(3) 1911–1930

1911 Cloud chamber
1915 Tank
1928 Penicillin

(4) 1931–1950

1931 Electron microscope
1933 FM radio
1935 Nylon
1938 Nuclear fission
1941 Polyester
1947 Hydraulic fracturing
Transistor
1948 Atomic clock

(5) 1951–1970

1953 Video tape recorder
1956 Hard disk drive
1957 IBM 610
Sputnik 1
1960 Laser
1967 ATM (Barclays)
1970 Pocket calculator

(6) 1971–1990

1971 Email
Intel 4004
1972 Magnavox Odyssey
1973 Capacitive touchscreen (CERN)
1975 Altair 8800 (Microcomputer revolution and internet protocol suite)
1980 Flash memory
1982 CD-ROM
1984 Cell phone
1990 World Wide Web
Hubble Space Telescope

(7) 1991–present

1992 Text messaging
1993 Apple Newton
Mosaic (Web browser)
1995 DVD
Windows 95
1996 USB ports
1997 Netflix
1998 Google
2000 Bluetooth
2001 iPod
2003 iTunes Music Store
2004 Facebook
2005 YouTube
2006 Twitter
2009 Bitcoin
2013 Bitcoin ATM

Note: Labour productivity index (1760=100) created using UK and US data. UK data from 1760 to 1889 taken from BoE's 'a millennium of macroeconomic data for the UK'. US historical series from 1890 to 2017 created using Kendrick (1961) and BLS (non-farm business sector; real output per hour) data. US and UK historical series spliced together to arrive at a longer data history starting from 1760 up until 2017. Source: Kendrick (1961), BLS, BoE, Barclays Research

New machine age: More than AI

Combination of new technologies

The 'new machine age' began in the mid-1970s…

… and accelerated in the 2000s

We broadly define the 'new machine age' as a development originating in the 1970s with the creation of integrated circuits and the related rise of (personal) computing power, which were then complemented in the 1990s and 2000s by the internet and other elements of new information and communication technology (ICT) (see Box 1). While the previous chapter focused on the possibilities of artificial intelligence (AI) and machine learning, a broader set of technological changes is driving economic change, including:

- **Digitisation**: For many digital products, marginal costs are (near) zero. This implies large economies of scale that lend themselves to 'winner takes all' outcomes and create a tendency towards natural monopolies. Digital products also blur the line between consumer and producer, as, for example, everyone can contribute to the production of online content (the birth of the 'prosumer').
- **3D printing**: Additive manufacturing (3D printing) facilitates the transition from 'mass production' to 'production by the masses'.
- **Robotics**: Rapid recent progress in robotics may overcome Moravec's paradox: that low-level sensorimotor skills require enormous computational resources (much more than high-level reasoning). New industrial robots are more versatile, cheaper and can be used in many more areas, including services.

'New' in the historical context

'Creative destruction' is not new, but the speed and scale of the current episode could be

One question is whether the effects of these new technologies will be different than those created by technologies in the past. Technological change and related structural economic change, including the decline of certain occupations and the rise of new professions, are nothing new in principle. History is full of examples of this process, described by Schumpeter as 'creative destruction'. These incidents create painful adjustment costs for some, but over time seem to have the positive net effect of creating more jobs with higher productivity and better pay for all (Figure 1). However, given the speed, scale and scope with which recent technologies are revolutionising our world, this new machine age could be truly different from previous episodes. While the question will remain unanswered for now, attempting to understand these ongoing developments and their consequences is very much warranted: these changes are affecting economies and societies, creating 'winners and losers' and posing challenges for policymakers.

Box 1: Key steps in the digital revolution

1970s-1980s: **Integrated circuits** – Tiny processors and memory on microchips, miniaturising and greatly speeding up calculations. The arrival of modern, fast personal computation meant for the first time serious computational assistance for the economy, eg, computer-aided design programs, real-time inventory tracking.

1990s-2000s: **Internet** – Connection of digital processes: linking of computers into networks via cable or satellite. Internet becomes a commercial entity, web services emerge, and computing resources are shared through the cloud. In a virtual economy, interconnected machines and software mean that physical processes can be executed digitally. Production processes can be unbundled and located across geographies wherever cheapest. Global value chains (GVS) are created, bringing about 'hyper-globalisation' (see also *The Future of Globalisation*)

Since 2010s: **Sensors** – Cheap and omnipresent sensors (radar, gyroscopic, magnetic, chemistry, pressure, temperature, moisture, etc), connected through wireless networks can collect vast amounts of data, available for analysis by intelligent algorithms. This makes possible computer vision, machine recognition of objects; language processing and translation, face and voice recognition, and digital assistants.

Source: McKinsey (2017), Barclays Research

Micro in nature, but macro in consequence

New technologies typically disrupt individual markets…

In principle, the direct implications of the new technologies are microeconomic in nature. Indeed, in their assessment of the 'new economy' in 2001, DeLong and Summers concluded that "the principal effects...are more likely to be 'microeconomic' than 'macroeconomic'."[1] They noted that the new technologies create the "possibility of lower average unemployment" and perhaps diminish "the inventory driven component of the business cycle", but overall judged these macro effects to be rather negligible. Instead, they note that "the microeconomic effects...are likely to be far-reaching", highlighting the powerful effect that zero marginal costs and increasing returns to scale could have on the functioning of markets.

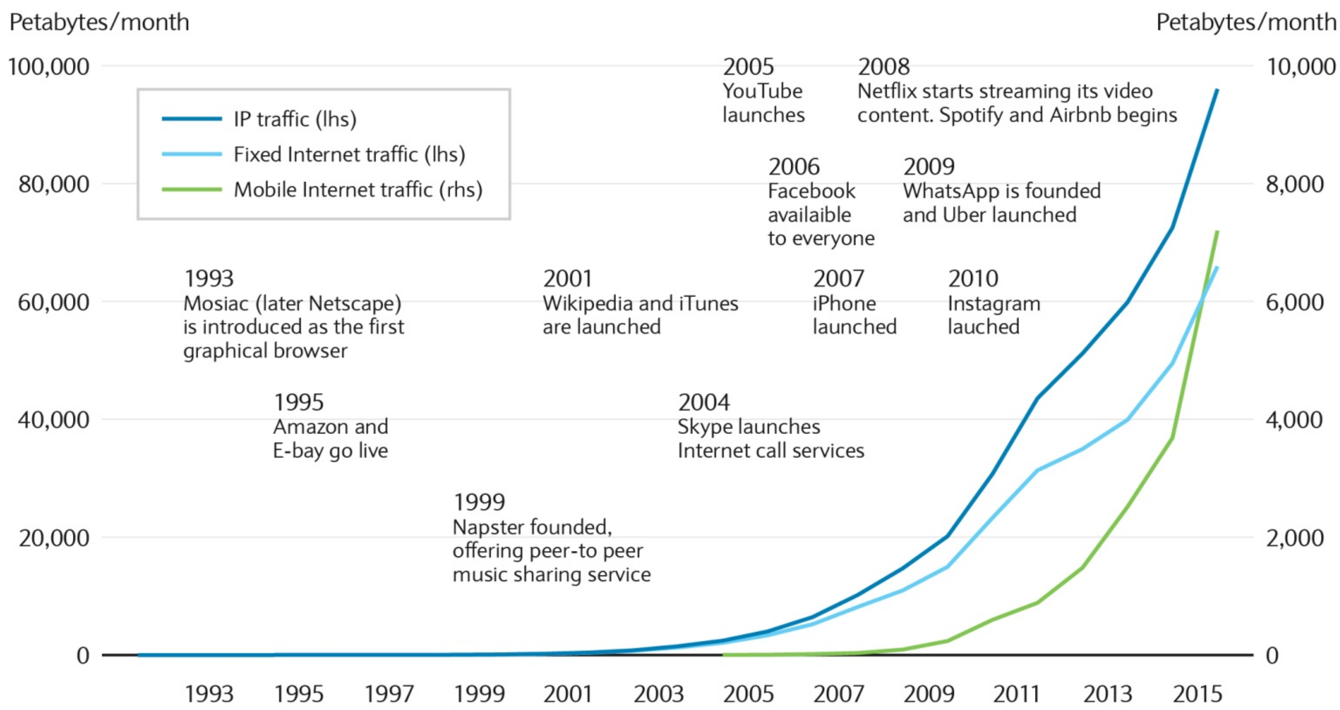
…but the scope of the digital revolution today seems to aggregate to macro effects

However, one and half decades and a global financial crisis later, the question of the macro effect may present itself in a different way: have the technology revolution's originally microeconomic effects added up to meaningful macroeconomic consequences? Perhaps the smoothing of business cycles through better inventory management was not the only and perhaps not the most powerful macroeconomic effect to consider. A number of macroeconomic puzzles have either emerged or deepened over the past 15 years, related to weak economic expansion, low productivity and wage growth, difficulties in reaching inflation targets, and a relentless decline in labour's share of overall national income.

Technology could therefore play a key role in explaining recent macro 'puzzles'

Some of these questions are related, and all are unlikely to have simple explanations, with the global financial crisis bearing some responsibility in recent years. However, against the evidence of rapid growth in robotics and the powerful disruption of traditional economies through e-commerce and technology-driven platforms (Uber, Airbnb), it seems plausible that technology is playing an important secular role. Some of these trends are more recent, while others are visible in the data since the mid-1970s, coinciding with the revolution in computing power and, thus, what we consider the beginning of the 'new machine age'.

FIGURE 2
Digital revolution has accelerated over the past decade



Source: Barclays Research

[1] J.B. DeLong and L. Summers (2001).

Economic growth in a digital world

Misery of measurement: The limitations of GDP

Proliferation of digital services leads to measurement issues

Perhaps the most fundamental question is how we measure economic progress and whether this is affected by the digital revolution we are experiencing (Figure 2). In the most direct, narrow sense, it is about correctly measuring growth – capturing the expansion of economic output, which allows us also to answer questions about productivity (the relationship between output and input) and per capita income. In a broader context, however, it is also about whether *output growth* is still the most adequate way to define the success of policies. Neither of these questions is new, but they have become much more pressing in a world where technologies profoundly change the structure of economies and the ways in which goods and services are produced, exchanged and consumed.

GDP was designed to measure production-based economies

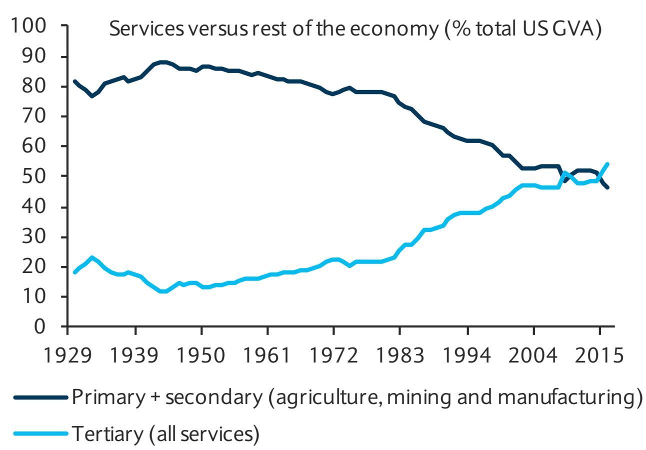
The well-established metric for economic growth – gross domestic product (GDP) – has always presented a number of challenges. Since its underlying System of National Accounts (SNA) was developed in the late 1930s (by Simon Kuznets), it was clear that it was a measure of 'production', not a nation's welfare or even individual well-being. Although this is pointed out at times (including in Robert Kennedy's famous quote that GDP "measures everything except that which is worthwhile"), GDP growth rates and GDP per capita are typically equated with 'living standard' or, even more broadly, 'success' in mainstream reporting. This may have been a justifiable simplification in a manufacturing-dominated world where meeting the demand for tangible goods (cars, TVs, refrigerators, etc.) was at the heart of improving people's lives. However, with the rise of the service economy and, in particular, the digitisation of goods and services, the challenges to the concept of GDP have been compounded.

The services component was always less well measured

When GDP was first introduced, manufacturing accounted for a large share of the core advanced economies, and the SNA concept was designed primarily to measure physical production. Since then, however, services have systematically grown in importance: from still less than 15% after WWII to over 50% today (Figure 3). Measuring output and prices for services is inherently more difficult than for goods. Services cover a wide range of activities and are often customised, making their basic unit of production, as well as differences in quality and changes over time, hard to define. The difficulty that statistics have with services is reflected in the fact that the SNA still breaks down manufacturing with much greater granularity than services, even though services now make up a much larger share of the economy.

FIGURE 3

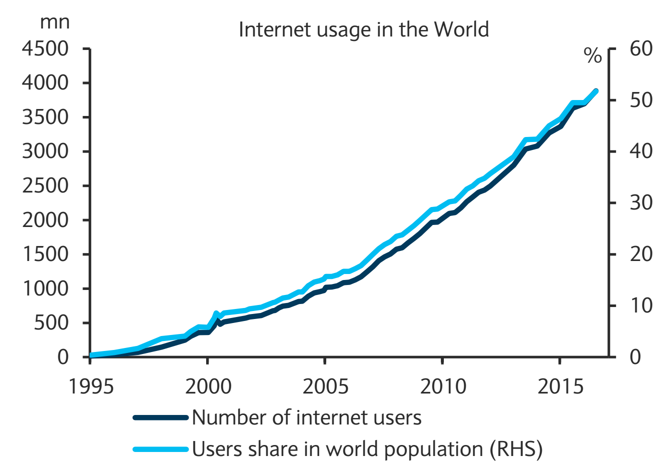
Services today account for more than 50% of US GDP…



Note: GVA data available only from 1947. Data prior to 1947 spliced using BEA data on services share in GDP. Source: BEA, Barclays Research

FIGURE 4

… and the digital economy is spreading rapidly



Source: *www.internetworldstats.com*, Barclays Research

Digitization exacerbates GDP's conceptual shortcomings

Computerisation and digitisation have amplified these issues (Figure 4). Services have become ever more complex, they are difficult to locate across jurisdictions, and the lines between manufacturing and services, as well as between work, domestic activity (home production) and leisure, are increasingly blurred.

Value of free digital product: Missing the *consumer surplus*

Digital goods, when free, are excluded from GDP

Digitised goods or services are often free; and without an observable market price, the SNA, by definition, excludes them entirely from GDP.[2] But just because the consumption of a digital product does not involve a monetary transition does not automatically mean that it is of zero value to the consumer. Thus, the current treatment of digital products within the SNA systematically underestimates the value generated by the digital economy.

Non-rivalry and network effects enable digital goods…

However, capturing the economic value of digital products is complicated by their particular characteristics: they are often non-excludable, ie, once on the internet, it is difficult to exclude anyone from consuming them, and they are non-rival, as their consumption by one agent does not affect their consumption by others. Indeed, their value may even increase with the number of users (network effects). Moreover, beyond the initial fixed costs, digital products have (near) zero marginal cost: they can be easily replicated, stored at negligible costs and sent over large distances. Indeed, given that the basic condition for economic efficiency is that price be equal to marginal cost, such a digital good *should* be priced at zero.

… to create large consumer surplus, not captured in GDP

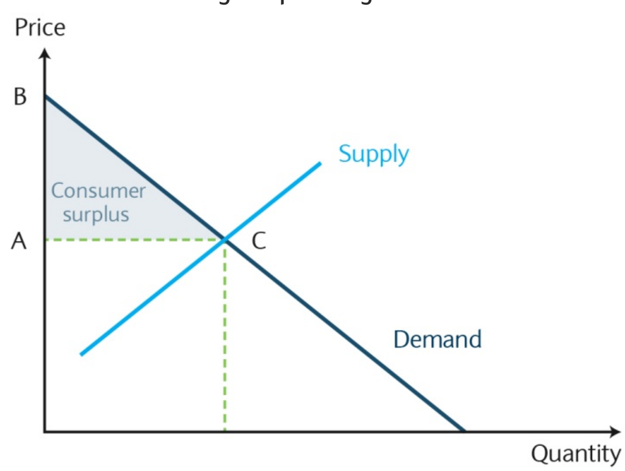
This phenomenon of consumers having to pay less for something than it is worth to them is also not new to economics. The difference between what consumers would be willing to pay for a good or service and what they actually pay is the concept of *consumer surplus*. It has mainly been discussed in the context of public goods (eg, national defense, lighthouses, free-to-air radio and television) (Figure 5), which share many characteristics with digital goods (non-excludability, non-rivalry, zero marginal costs) and are (or, for the sake of economic efficiency, should be) provided free of charge.

Using input costs likely underestimates effect on GDP

As the issue of free public goods is addressed in the SNA by measuring the value of inputs used in their production, one approach could be to capture the digital economy in a similar way: eg, use the advertising value involved with digital products as the input value for their production (Figure 6). However, when marginal costs are near zero, the true value of a good is unlikely to be captured by such a cost-based approach. Indeed, advertising expenditure is

FIGURE 5

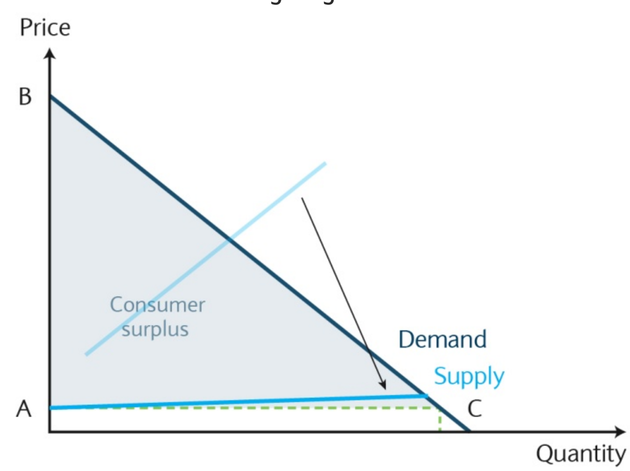
Consumer rent for regular private goods



Source: Barclays Research

FIGURE 6

Consumer rent for free digital goods



Source: Barclays Research

[2] It is true that firms that provide digital products may charge others for advertising space, but for aggregate GDP this is a wash under the current SNA treatment: treated as intermediate input, the same value is for the industry that sells the advertising space but subtracted from the industry that pays for it. Only if, as a consequence of the advertising, additional goods and services are sold would GDP increase. See also Bean (2017).

only a small share of GDP, typically resulting in low estimates for the value added from the digital economy. The approach also ignores the value of digital services produced without requiring compensation, such as blogs and Wikipedia entries, which are freely produced by participants without advertising. This is one of the aforementioned examples in which the digital economy blurs the line between producer and consumer, leading to the term 'prosumer' in a digital economy.

Treating data flows as proxy for digital production has its own shortcomings

Another approach within the existing SNA framework would be to treat *data* in a manner similar to goods. This would put the focus on measuring data generation, flows, use and storage as a way of capturing digital activity. Hence, the mere growth of internet traffic becomes a proxy for growth in the consumption of digital product. However, this raises other questions: eg, how to treat increased data flow in a year when, given the usual flat rate internet subscription fees, the subscription price remains unchanged. It would imply a large 'quality improvement' in internet service, in turn requiring a downward revision to official price statistics; thus, higher real GDP growth would be associated with lower inflation.

Digital goods' value added is also difficult to locate in space

An additional complication for both approaches is the aspatial nature of digital products: while it may be possible to locate the consumer who downloaded a product, the location of production is less clear. Digital products are easily sent long distances and across jurisdictions. This is a non-negligible issue, as it could alter the measure of imports and exports and, thus, add to or subtract from a country's GDP.

Experimental methods could help establish 'shadow prices' for digital goods…

…as a way to capture consumer surplus

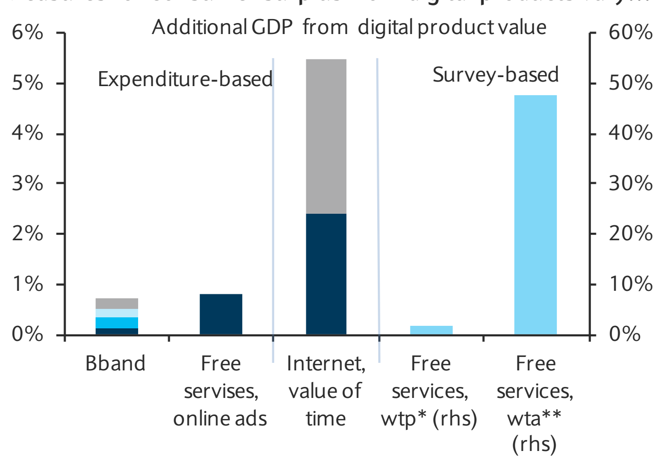
One way to capture consumer surplus more directly would be to value the amount of time a person gives up to access the digital product: ie, estimate the *opportunity cost* based on the assumption that every hour spent on the internet could otherwise be used working or for leisure activities. Treating the wage rate as the *shadow price* of leisure has some tradition in economics and has been used to compute value for non-market home production activities, such as cooking, ironing and cleaning. Recently, experimental methods (so-called choice experiments or lotteries) have been used to determine shadow prices for digital products: consumers are asked directly for the price that they would, in principle, be willing to pay for access to services (such as Facebook and Instagram) or, alternatively, that they would demand for giving up the relevant service.

Overall, annual GDP growth rates are likely underestimated by between 0.1pp to 0.75pp

Measuring consumer surplus this way can imply a significantly higher GDP, as much as an additional 48% in some studies. Other, more conservative, expenditure-based methods produce estimates from 0.1% to 5.5% (Figure 7 and 8). Expressed as gains in annual GDP growth rates, estimates vary similarly from 0.10pp to 0.75pp. However, the key message is

FIGURE 7

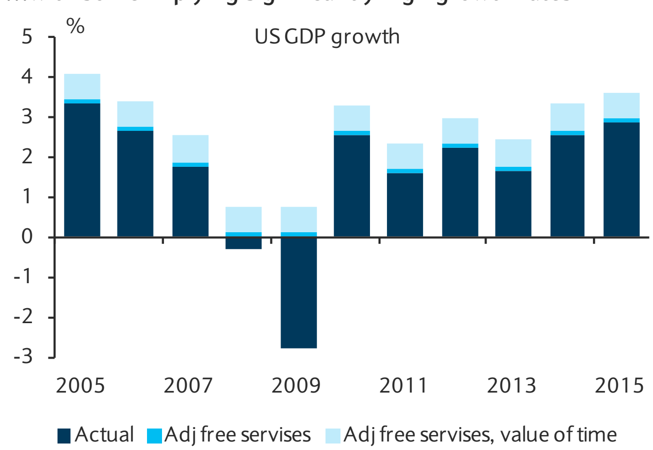
Measures for consumer surplus from digital products vary…



Note: * wtp = willingness to pay, ** wta = willingness to accept. Source: See list of articles in Figure 9, Barclays Research

FIGURE 8

…with some implying significantly high growth rates



Source: See list of articles in Figure 9, Barclays Research

FIGURE 9

Consumer surplus estimates

CS, bn $ (2015)	CS, share GDP (2015)	Type	Method	Source
22	0.12%	Broadband	Expenditure, survey WTP	Greenstein, McDevitt (2009); Syverson (2016); Barclays Research
64	0.35%	Broadband	Expenditure, survey WTP	Rosston, Savage, Waldman (2010); Syverson (2016); Barclays Research
96	0.53%	Broadband	Expenditure, WTP	Dutz, Orszag, Willig (2009); Syverson (2016)
132	0.73%	Broadband	Expenditure, WTP	Nevo, Turner, Williams (2015); Syverson (2016)
150	0.83%	Free content	Expenditure on on-line ads	Nakamura, Samuels, Soloveichik (2017)
324	1.79%	Free content	Survey WTP	Brynjolfsson, Eggers, Gannamaneni (2017); Barclays Research
439	2.42%	Free content	Value of time	Brynjolfsson, Oh (2012); Barclays Research
995	5.49%	Internet access	Expenditure, value of time	Goolsbee, Klenow (2006); Syverson (2016)
8646	47.72%	Free content	Survey WTA	Brynjolfsson, Eggers, Gannamaneni (2017); Barclays Research

Source: Barclays Research

that GDP misses a great deal of consumer rent associated with free digital products, and this will only increase as the digital economy grows.

Disintermediation and 'sharing': Lowering GDP

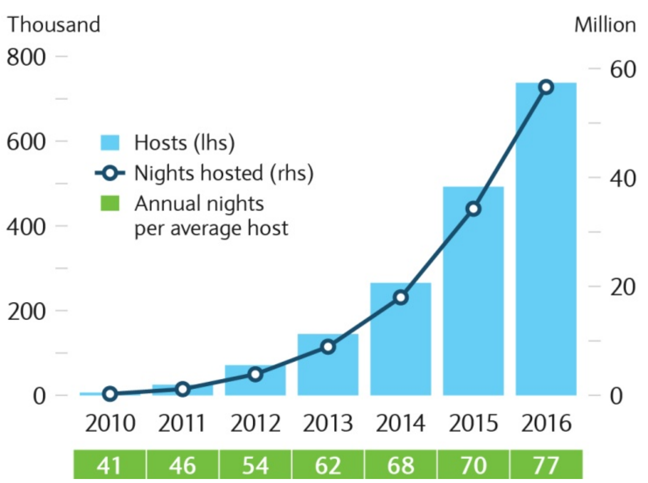
While new digital services are not fully reflected in GDP…

… the activity they replace is recorded a loss of GDP

While quantifying the value of digital goods may be the most fundamental challenge, the digital economy creates a host of additional complications for GDP measures. These challenges may not be new in principle, but are now present in such unprecedented scope and scale that they are difficult to neglect. Consider the dramatic disintermediation caused by internet–based business models. By directly connecting customers, suppliers and producers, they cut out the middlemen (eg, the travel-booking industry) and their related service commissions. Instead, the job is done directly by the consumer, reducing transaction costs and improving efficiency. However, in the SNA, this means that activities previously undertaken by the market economy (for a market price) have now become part of 'home production', which, by convention, is not counted as part of GDP. Hence, the ongoing disintermediation shifts activities outside the GDP boundary, driving it lower. For example, while the vast service Wikipedia provides to millions goes unnoticed by GDP, the loss in sales of encyclopaedia books will reduce GDP. Certainly, if the consumer's cost savings then lead to some other activity, this could be offset, but only if it falls into one of the categories captured by GDP.

FIGURE 10

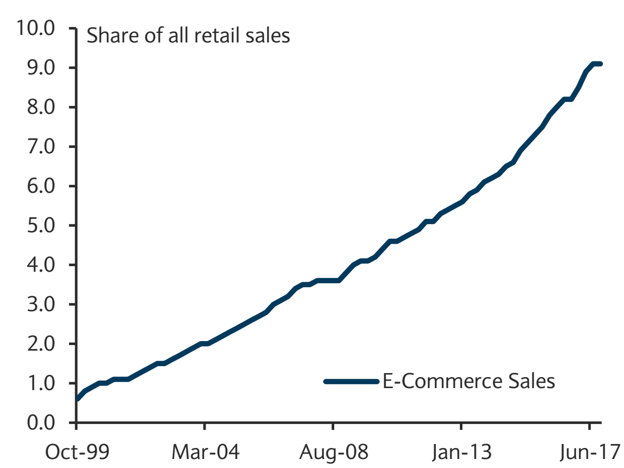
'Sharing': When households become hotels



Note: European markets are Germany, Italy, Spain, and the United Kingdom. The number of hosts shown in this figures are 'hosts who hosted'. Source: Airbnb (2017), "Airbnb data for OECD study", Barclays Research

FIGURE 11

Ecommerce: When competition comes through the internet



Source: US Census

'Sharing' likely overstates actual prices, reducing measured real GDP growth

The 'sharing' economy is another example in which the lines between work and leisure/ business and household become blurred and activities are shifted outside the scope of GDP (Figure 10). The sharing of accommodation (Airbnb) or transport (ZipCar) implies a shift in ownership to rental on demand. This is conceptually not entirely new to the SNA, but shifts rapidly growing activities to unincorporated individuals. Beyond the issue of whether this distorts labour market statistics and measures of household income – similar to those participating in the 'gig economy' (eg, through sites such as Freelance.com or TaskRabbit, see Box 4) – it also raises questions about the correct measure of prices (Figure 11). For example, if price information is sourced entirely from businesses (as in the case of the UK's ONS), the likely lower prices that consumers pay for rooms rented on Airbnb rather than traditional hotels would not be picked up in official statistics. This implies the use of an elevated GDP deflator (ie, too much inflation) and lower real GDP growth, a phenomenon that presents a broader challenge in a world of rapidly changing products where statisticians have to control for quality effects. Box 5 explores these effects in greater detail.

Quality improvements: Over-recording inflation at the expense of growth

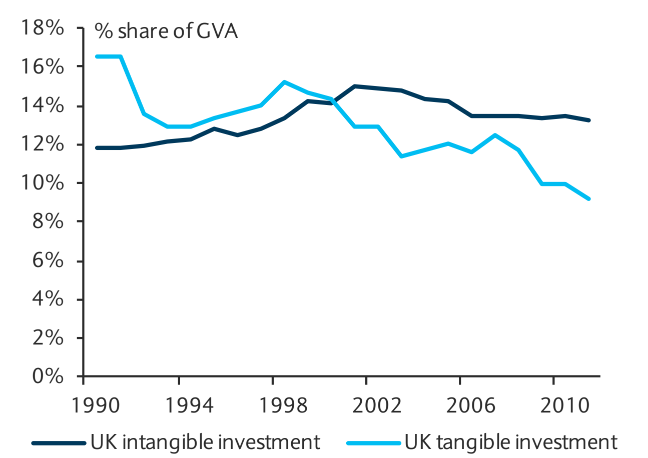
Digitisation–driven quality improvements often lead to overstating inflation and understating GDP growth

Prices and their changes over time are also crucial for another important issue that has been magnified by the rapid advances in technology: accounting for quality improvements. Failing in this can lead to a biased measure of real GDP growth. Statisticians measure GDP-included activities at their market prices, then have to determine which part of the change in price was due to inflation and which was from an improvement in quality. Again, this has always been the case, but has become much more complicated with the rising share of digital services and rapidly evolving electronic goods.

The Boskin commission found that failing to account for ICT quality changes overstated US CPI by 1.1% per year…

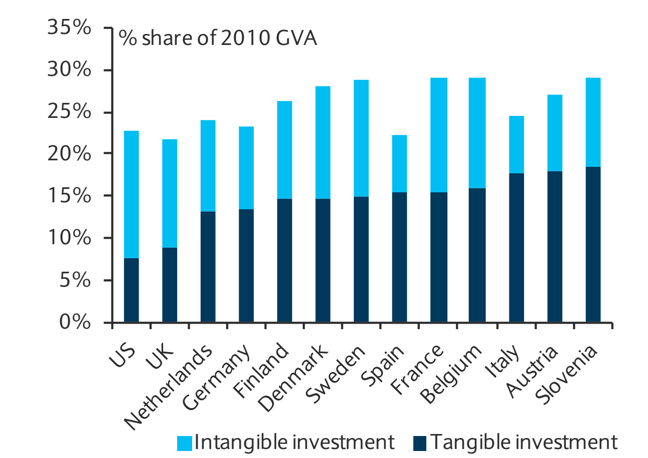
In 1996, the Boskin Commission in the US calculated that because of the rapid advances in a few goods such as computers and phones, the US had overstated US CPI inflation by 1.1pp per year and, by the same token, underestimated real GDP growth (because of excessive GDP deflators). The changes that were implemented thereafter were meant to reduce the bias to 0.6pp from 1997 onwards. In his 10-year review of the commission work, the US academic Robert Gordon argued that due to quality improvements, the bias was back to between 0.8pp to 1pp. Similar reviews in the UK (eg, Paul Johnson's in 2015) also emphasised the need for adequate price adjustments, as did recent reports by the ONS. In January 2018, ONS officials highlighted a "disconnect between the technical performance and the economic measurement of [the telecoms] industry" related to telecoms' offering of much improved data and network services at unchanged market prices in recent years. As a

FIGURE 12
UK investment in intangibles exceeds that in tangible capital



Source: Goodrige, Haskel and Wallis, NESTA Working Paper 14/07

FIGURE 13
Intangible investment is crucial across economies



Source: Corrado, Haskel, Jona-Lasinio and Iommi (2012)

…but despite methodological improvements, this 'bias' was back to 0.8-1% by 2006

consequence, the real growth of this sector (and, thus, aggregate GDP) was too low, while the related inflation measures were too high.[3] This is unlikely to be an isolated example for the UK, illustrating the ongoing challenges of reflecting rapid ICT changes properly in the existing GDP and inflation measures. Following the numbers provided by Gordon, we think that the overstatement in CPI inflation could be as large as 0.6-1% per year.

Intangible investment: Just consumption to GDP

GDP accounting classifies intangible capital as intermediate consumption…

A final measurement issue relates to the definition of *investment*. In an economy that shifts from (physical) capital-intensive to knowledge-intensive production, *intangible capital* becomes increasingly important. This encompasses all assets contributing to the long-term accumulation of knowledge (including human capital), research and development, or information stored in software. Although key for driving economic growth as a complement to physical capital, the SNA considers the acquisition of intangible assets to be intermediate *consumption,* rather than investment.

… neglecting intangibles' role in driving growth and productivity

This (mis)classification is not negligible. Some estimates suggest that in economies such as the UK, investment in intangible capital has surpassed physical capital investment since the early 2000s (Figure 12). Indeed, recent academic research suggests that treating intangible assets in the same way as physical capital would significantly increase the overall recorded investment for many economies and reduce some of the current differences in investment between countries (Figure 13).[4] Furthermore, omitting intangible investments can also add *J-curve effects* to productivity measures. When national accounts fail to account for the production of intangible capital that has not yet led to an increase in measured final output, this implies a loss of output (lower GDP). Later, the returns from the stock of this unmeasured capital create measured output, which is then incorrectly attributed to total factor productivity (TFP)

Technology and prices: 'Good' deflation?

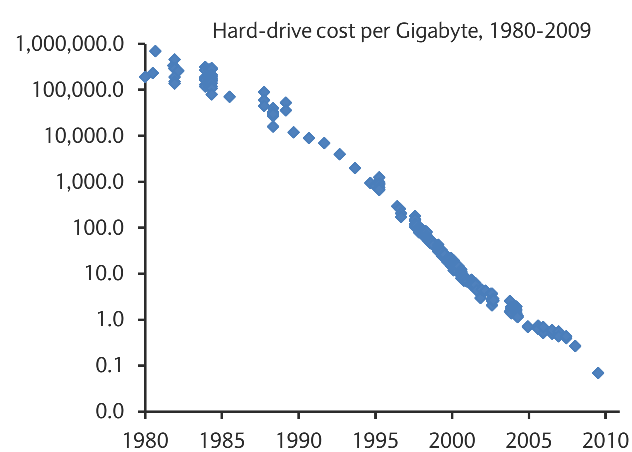
Technological disinflation

Inflation rates have fallen since the 1980s …

Inflation rates have been falling around the globe, from historically high levels in the 1970s and 1980s to very low levels at the start of the 21st century. Better monetary policy regimes (ie, inflation targeting) and economic liberalisation, including more flexible labour markets

FIGURE 14

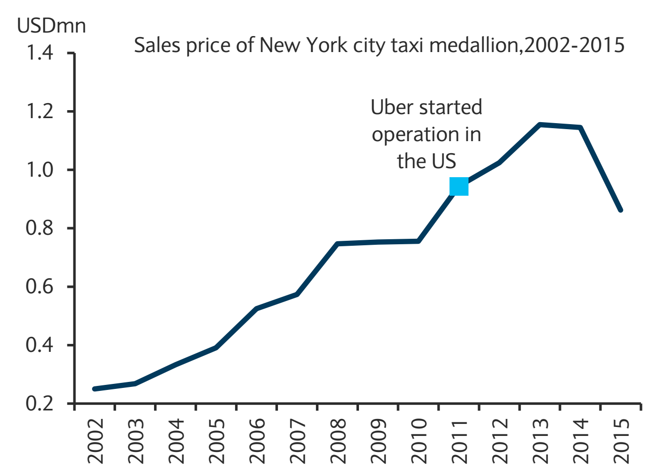
Collapsing prices in ICT directly affect inflation



Source: *http://www.mkomo.com/cost-per-gigabyte*, Barclays Research

FIGURE 15

Competition from new business models



Source: Wei and Mozur 2014; Metropolitan Transportation Agency (New York), http://www.mta.info/; Golovin 2014, Barclays Research

[3] *Financial Times,* 18 January 2018.
[4] Bean (2017)

and open trade (ie, globalisation), especially the integration of China with the global economy, have contributed to this global disinflation. This was widely regarded as a positive development, as inflation stabilised around (low) official inflation targets in parallel with robust output expansion, signifying a 'great moderation'.

…and continued to fall since the 2008 global financial crisis

In the aftermath of the 2008-09 global financial crisis, however, inflation rates fell below official targets, in some cases into outright deflation. Central banks embarked on unorthodox measures such as QE and negative interest rates to push inflation higher, but with limited success. The severity of the crisis, along with the high unemployment and large (and possibly underestimated) output gaps it created, could explain this initially. However, even as growth recovered and unemployment rates fell to levels typically associated with full employment, inflation remained suspiciously absent.

Globalisation's moderating effect on inflation may have peaked …

…but the disinflationary effect from technology has not

This raises the question of whether beyond the cyclical drivers, secular trends may be at work. Our previous research (*Equity Gilt Study 2016, Fight to bring back inflation*) concluded that global inflation trends seemed to have been increasingly driven by a 'common global factor' even before the global financial crisis and that labour market factors had likely become most relevant. In line with this, recent research suggests that GVCs could play an important role in global disinflation.[5] Although this globalisation through expansion of GVCs seems to have stalled, technological change has not. Could technology be behind the common factor that is lowering global trend inflation?

Technological progress can, in principle, affect inflation through three channels:

1. A direct effect on prices for technology products;
2. Effects on (retail) margins through changes in market structure and competition; and
3. Effects on firms' production costs through efficiency gains and automation.

Technology lowers inflation directly through cheaper ICT products…

The first channel is well documented by the sharp declines in computing equipment and ICT-related hard- and software (Figure 15). As explained above, the effect may often even be underestimated because of improper adjustments for quality improvements when measuring inflation. The other two channels warrant further exploration.

Amazonification and the pressures from e-commerce

…and indirectly through intensified competition and pressure on margins

The second channel works in various ways: the internet and technology reduce barriers to entry: digitisation allows any firm, including small, niche firms and start-ups, to reach potential customers faster and at a lower cost across the globe. This increases competition for incumbents from foreign competition, as well as from digital firms invading non-tech sectors (Figure 16). The rapid rise of e-commerce accelerates this by creating extreme price transparency and comparability. As a consequence, consumers can switch their purchases to cheaper online sources, which may force (traditional) retailers to lower their prices. The emergence of large lower-priced online sellers such as Amazon has magnified this spillover effect on (traditional) retailers' prices (the Amazon effect). As the share of online retail increases, the differential between on- and offline prices will have a growing influence on inflation.

[5] BIS/Borio 2017,

Box 2: AirBnB and Uber's impact on the UK's GDP growth and price deflators

AirBnB and Uber are popular digital services providers, which have significantly disrupted the markets they operate in. They affect GDP and price measurement in different ways, which we try to illustrate for the UK:

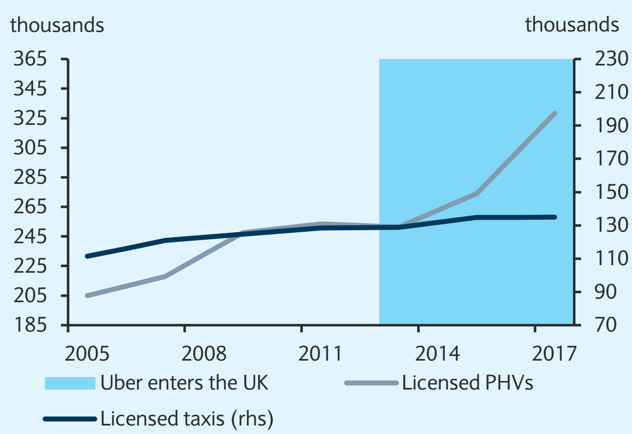
AirBnB is a platform that allows home owners to rent out underutilized space, effectively competing with hotels. As pointed out in the Bean Review, Gross Value Added in the UK's accommodation sector, which is about 0.7% of the economy, is deflated by a weighted average of the services PPI and the CPI, which include hotel prices, but not AirBnB prices. Analysis by Priceeconomics (2013) suggests that renting a flat through AirBnB was 20% cheaper than a hotel, while renting a single room was 50% cheaper. It is of course difficult to know if the quality of the provided services is higher or lower, which depends on whether guests prefer access to a kitchen over the many amenities available at a hotel. Regardless, this line of argument suggests that excluding AirBnB prices from the price deflator means that the real gross value added is actually understated. Furthermore, if surveys do not full capture the use of AirBnB, and not all of the income is declared in taxes, even the nominal value added could be understated. But how much do these effects matter quantitatively? The Bean review cites AirBnB research that indicated a spend of £243 million and suggests that the real gross value added of accommodation services would be higher by 0.7% as a result. Given that this sector makes up only 0.7% of the overall economy, this seems small at first sight. However, if this effect was translated to the overall economy, the magnitude would clearly be much larger.

Uber, a company that matches drivers in a given area to demand for taxi services, can at least be partially picked up in national statistics through cost of input measurement. According to the Bean Review, the Department for Transport surveys the licensing authorities every two years to record new private hire vehicles, which also include those drivers who rely on app-based services like Uber. The latest data, collected in 2017, suggests that the number has increased 30% since the introduction of Uber in the UK, equating to roughly 20,000 more private hire vehicles per year (Figure A), while the number of taxis stayed flat. Uber is thus at least partially picked up in national accounts through the cost of acquiring one production input, the car, to run the business. Figure B shows that the output per worker in this sector, labour productivity, rose initially, but then began to fall. This is because a rise in competition likely reduced the margin (profits) of individual taxi drivers. At present, therefore, each additional Uber driver adds to GDP at a decreasing rate. However, this does not include the consumer surplus from access to more easily available transportation services. Overall, the case of Uber illustrates the challenge of fully capturing the value added by digital services, even if some information on the costs of inputs is available.

Source: Priceeconomics (2013), The Bean Review (2016), Department for Transport, UK Office for National Statistics

FIGURE A

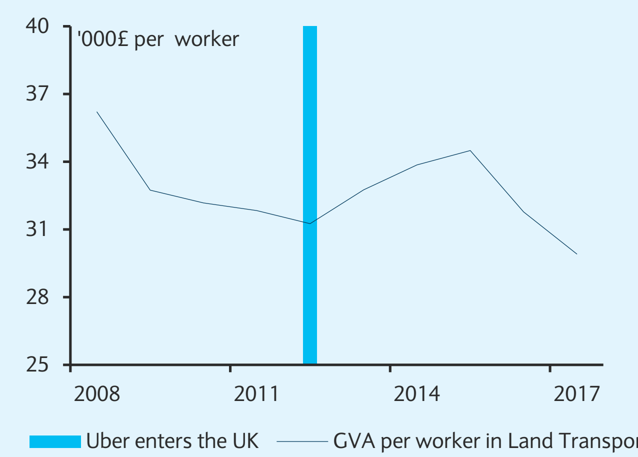
Uber led to a 30% in UK Private Hire Vehicles since 2012…



Note: Department for Transport, Barclays Research

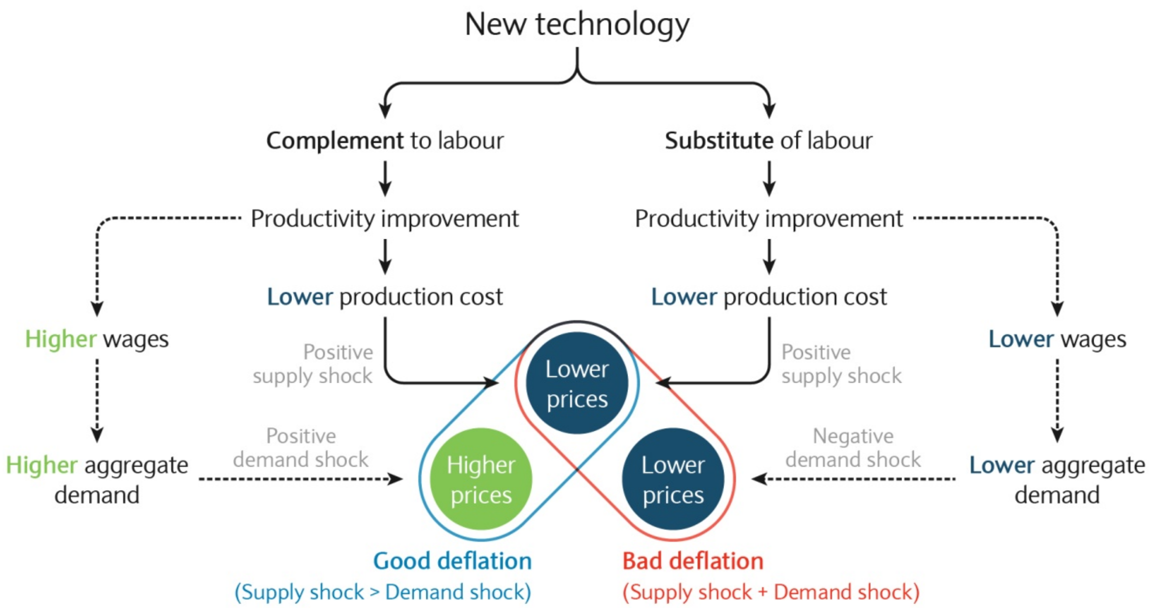
FIGURE B

…but productivity in the sector rose at first before declining



Source: UK ONS, Barclays Research

FIGURE 16
Technology and prices: 'Good' versus 'bad' deflation



Source: Barclays Research

Digital enterprises' scale creates savings that are passed on to consumers…

…while low entry barriers may curtail their monopoly power

The Amazon example also hints at a second way that the market structure channel works: digital technologies, with their (near) zero marginal costs and important network effects, lead to 'winner takes all' outcomes: the emergence of dominant firms with the market power to force traditional and smaller participants out of the market. A priori, the effect of this change in market structure on inflation is ambiguous: on the one hand, such dominant firms can lower prices because of their lower costs, but once they have gained (quasi-) monopoly market power, they can use this to increase prices. In practice, however, overall price pressures appear to be primarily downward, as these firms seem to pass on significant cost savings to consumers. Indeed, the ease with which new competitors can enter the digitised market (ie, contestable markets) may mean that even dominant firms cannot translate market dominance into increased pricing power.[6]

Automation: Machine versus wage

Wages are the underlying driver of inflation

The third channel of technology-driven effects may be the most complex but also the most relevant, since it will likely have the most persistent effect on inflation dynamics over time. It relates to the relation between labour and capital and the question of whether technology improvements are predominantly labour-augmenting (complements) or -saving (substitutes).

Productivity gains typically have led to higher wages

When technology acts as a complement to labour, the associated productivity boost is a positive supply shock that translates into lower prices (a positive supply shock), which could be seen as 'good' disinflation (or even 'good deflation') (Figure 16). At the same time, higher productivity should also translate into higher wages, which, by increasing disposable income/aggregate demand, should over time exert some upward pressure on prices, thus offsetting the deflationary effect. For example, it has been argued that 1880-1913 represents a case of 'good deflation' for the economies of the US, the UK, and Germany: technology drove aggregate supply to expand more rapidly than demand, causing prices to fall at a moderate rate (with the additional complication that this occurred under the gold standard).[7]

[6] Bank of Canada (2017).
[7] Bordo/Lane/Redish (2004): *Good versus bad deflation: Lessons from the gold standard*.

But if machines substitute rather than complement labour, wages may not rise

In contrast, in 'bad' deflation, the demand-supply gap is driven by a decline in aggregate demand. This could be the case when productivity improvements are achieved by technologies that mainly substitute labour (eg, automation) because then, next to the positive cost saving/supply shock, the disinflationary effect is magnified by the negative demand effect from falling wages and lower employment.

Disentangling these effects in practice may be challenging, but labour market-related developments over the past decades suggest that new technologies affect wage inflation. Beginning in the mid-1970s to early 1980s, coinciding with the breakthroughs and expansion of personal computing, data on wages, income and productivity suggest that some of the assumed laws of economics may have become unstuck:

- Median wage and productivity growth, which maintained a constant and strong relationship for 150 years, seem to have decoupled, as wages have been weaker than can be explained by the recent slowdown in productivity.
- Wages and the unemployment rate – the much relied-upon Phillips curve dynamic – has weakened, as wages have not accelerated despite low unemployment, suggesting a significant flattening of the curve.
- Labour's share of income, assumed to be stable in macroeconomic models, has declined continuously and significantly.[8]

Productivity gains since the 1970s have not translated into higher median wages

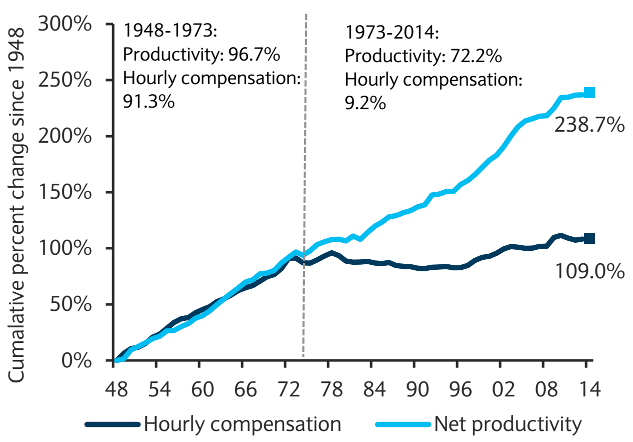
Since the mid-1970s, median wage compensation has started to diverge from labour productivity. Hence, during a period that included phases of both slow and rapid productivity growth (eg, 1995-2004), wage growth has not kept up with productivity developments (Figure 17 and 18). Technological change is unlikely to be the sole factor affecting the relationship: declining unionisation and other changes in wage bargaining powers have likely played a role, but it is nevertheless striking that this relationship held relatively stable over the previous 100 years, when all other possible factors underwent large changes as well.

The ICT revolution benefitted skilled workers…

In the previous chapter, we discussed in more detail how new technological advances are affecting wage developments and employment. One highlight is that computer technology has led to significant income shifts between workers with different skill sets. It has created downward pressure on routine activities – typically, middle-skill, middle income jobs – that can be substituted. At the same time, it has resulted in higher wages for activities – typically, higher-skill jobs – that would be complemented by technology.

FIGURE 17

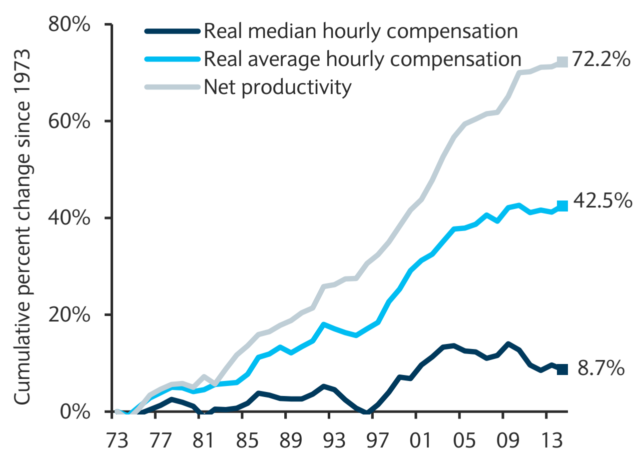
Wages have decoupled from productivity since mid-70s



Source: EPI analysis of data from BEA and BLS, Barclays Research

FIGURE 18

…with the median wage, in particular, lagging significantly

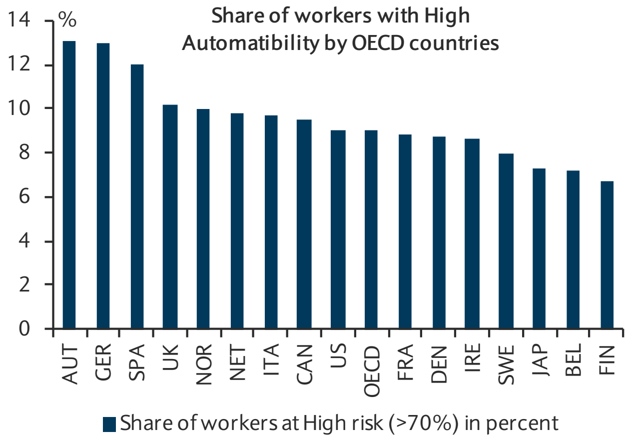


Source: EPI analysis of data from BEA,BLS, and CPS ORG, Barclays Research

[8]Karabarbounis and Neiman (2013); Kaldor (1957).

FIGURE 19

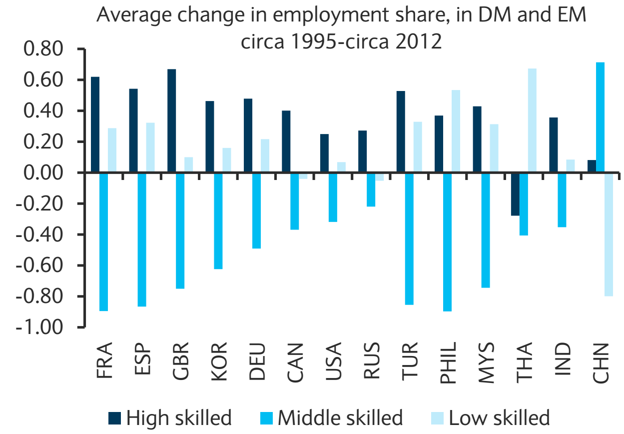
Automation is becoming a real and present possibility…



Source: Arntz, M., T. Gregory and U. Zierahn (2016), Barclays Research

FIGURE 20

… which thus far has mainly affected middle-skilled workers



Source: WDR 2016 team, based on ILO Laborsta (various years), The International Income Distribution Data set (I2D2) (World Bank, various years), National Bureau of Statistics of China (various years), Barclays Research

…but routine-skills jobs began to disappear…

…leading to stagnant wages in the affected sectors

This 'routine bias' also means that sectors requiring manual-non routine tasks – typically lower-skill jobs – have largely escaped the pressure from substitution through technologies so far, leading to a *polarisation* (a hollowing out of the middle). As the scope of automation expands, such 'technologically stagnant' service sectors (eg, health care, education, food and accommodation) could experience pressures as well. Hence, if anything, it seems that future automation will continue to limit the room for wage growth for middle- and low-skilled workers (Figures 19 and 20). As a consequence, it may never regain the significant role it played in inflation dynamics in the past.

Trade and development models revisited

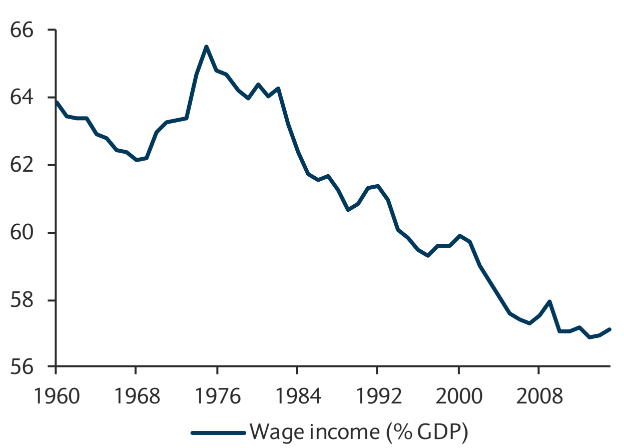
Re-shoring and the end of Global Value Chain trade?

Global value chains exploit labour cost differences…

The distributional effects associated with globalisation in advanced economies – eg, manufacturing workers suffering from intensified import competition – have created a political backlash. Among the most prominent examples are the recent trade and tariff

FIGURE 21

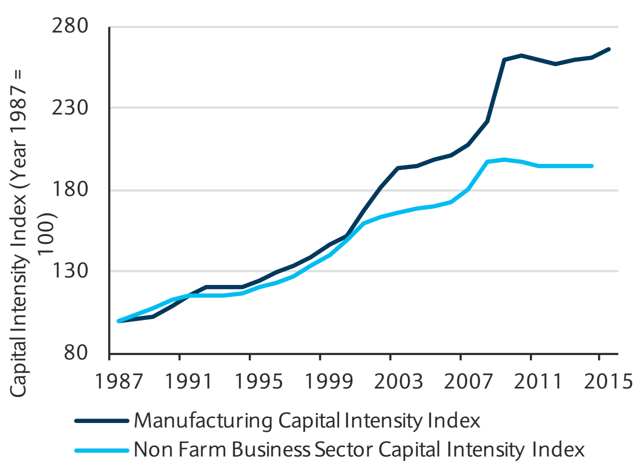
Not only have wages slowed, but labour's share in GDP has also declined…



Source: AMECO, Barclays Research

FIGURE 22

… as labour has been substituted for capital



Source: Charles, Hurst and Schwartz (2018), NBER WP 24468 policies in the US, which explicitly state the intention to protect domestic industries and bring manufacturing jobs back to the US. Reports of some 're-shoring' of activities back to the US may be seen as success of such policies. However, something more structural may be going on, driven by technology rather than policy.

…but new technologies make such differences less important

… allowing for re-onshoring of activity

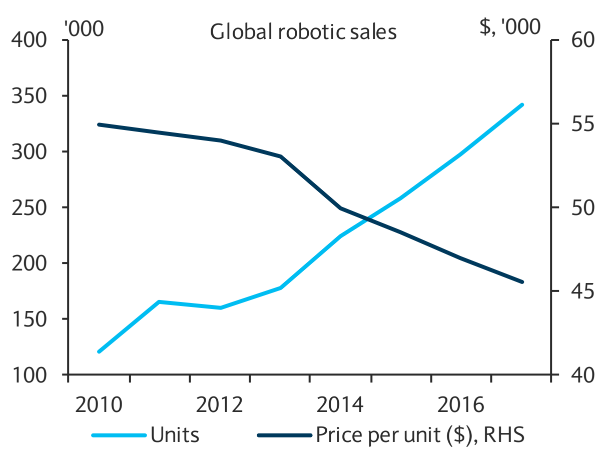
As discussed in *The Future of Globalisation*, the core concept of GVCs is to split production processes into intermediate steps in order to exploit factor income differences (typically due to different factor endowment) between countries. This dispersion of the production process across countries automatically means that more trade takes place for a given final output. Hence, much of the trade increase since the 1990s can be explained by the integration of EM economies into GVCs, especially China. However, recent progress in technologies such as 3D printing and new collaborative robots may turn this around: 3D printing unifies production back into one integrated process rather than a differentiated chain. At the same time, cheap collaborative robots make access to inexpensive manual labour less important, if not unnecessary.

Premature industrialisation and the developments ladder

This could challenge the industrialization model that developing countries followed in the past seven decades

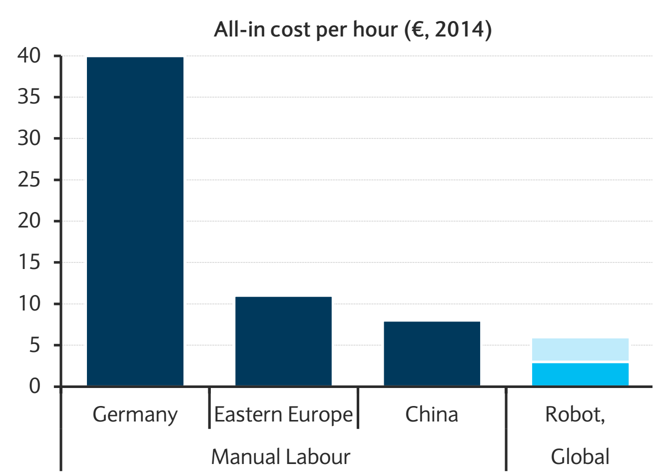
This not only puts into question certain GVCs, but also raises questions about the fundamental development model for poorer countries. Long before GVCs and the rise of China, other economies such as Taiwan and Korea successfully moved their abundant and cheap labour from less productive jobs in agriculture into export-oriented manufacturing positions. With industrialisation, productivity improved, wages rose and so did income per capita, similar to China's development more recently. As these economies catch up, they tend to shift from investment to consumption, implying somewhat lower trade intensity. The shift in comparative advantage associated with becoming richer implies that other, less developed EM economies will take over from the more mature EM economies. Indeed, the shift of textile and other labour-intensive manufacturing from China to Vietnam and Bangladesh (as Chinese wages have increased) is an example of this. Firms move on and their GVCs move with them. Further destinations could be the labour-rich economies in Eastern Africa, assuming an extrapolation of past developments.

FIGURE 23
The spread of cheaper robots …



Source: IFR, Kuka, Barclays Research

FIGURE 24
… makes off-shoring to cheap labor destinations obsolete



Source: VW, Barclays Research

Collaborative robots make the abundance of cheap labour less of a production advantage

Because robots can modify the relative factor intensities in the production of goods and services, they sever the link between cheap labour and the location of unskilled manufacturing activities. In other words, to the extent that relative factor endowments determine the international division of labour, the use of robots, also including technologies such as 3D printing, can move the location of manufacturing back to advanced economies. Admittedly, the challenge is not entirely new. Although industrialisation has historically been synonymous with development, recent trends show that many developing countries – especially in Africa and Latin America – have witnessed their share of manufacturing employment and output shrinkage long before they have attained income levels comparable with those in more developed economies. Such 'premature deindustrialisation' began as early as the 1980s and 1990s.[9] It has continued since, and the spread of new automation technologies and AI could accelerate it (Figure 25).

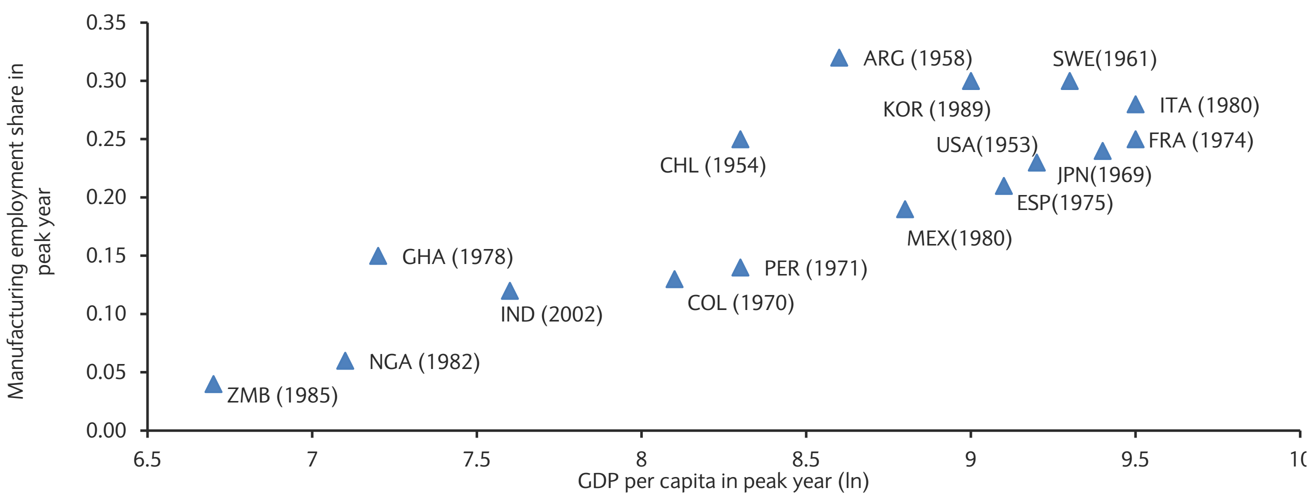
In principle, emerging and developing economies could also use robots. In fact, each year since 2013, China has bought more industrial robots than any other country, and it is expected to maintain its front-runner status (even if robot density – robots per industrial workers – there is still lower than in Germany, Japan, and Korea) (Figure 24). However, China embarked on its government-backed robotisation strategy in response to a shrinking working-age population and rising labour costs. But it makes less sense for developing economies that still have a large pool of cheap labour. The major challenge for these countries is to create jobs for a large number of low-skilled entrants to the labour force, such as in many parts of Africa. Deploying robots under current cost structures and low-skilled to high-skilled worker ratios could drive production costs up, rather than down.

May developing countries have to revert to lower value-added commodity exports?

Paradoxically, the new labour-substituting technologies could move global trade back toward the world that existed before the initial ICT technologies of 1980s and 1990s enabled the creation of GVCs, with north-south trade dominated by exports of raw materials against finished industrial goods. Raw materials, including new demand for materials such as lithium and cobalt/nickel for the production of batteries will continue to be needed and are often highly concentrated in particular geographies.

FIGURE 25

Automation could accelerate 'premature deindustrialisation', raising doubts about traditional development strategies



Source: Employment data based on Timmer et al. (2014), and GDP per capita is obtained from Bolt and van Zanden (2014) and are measured in $1990GK. The year in which the manufacturing employment share peaked is given within parentheses, and a fitted OLS regression line is also shown.

[9] See Rodrik, D. (2015), "Premature Deindustrialization";

Policies in a machine age

Beyond GDP: Measuring well-being

Policy may need to be based on more comprehensive measures than GDP

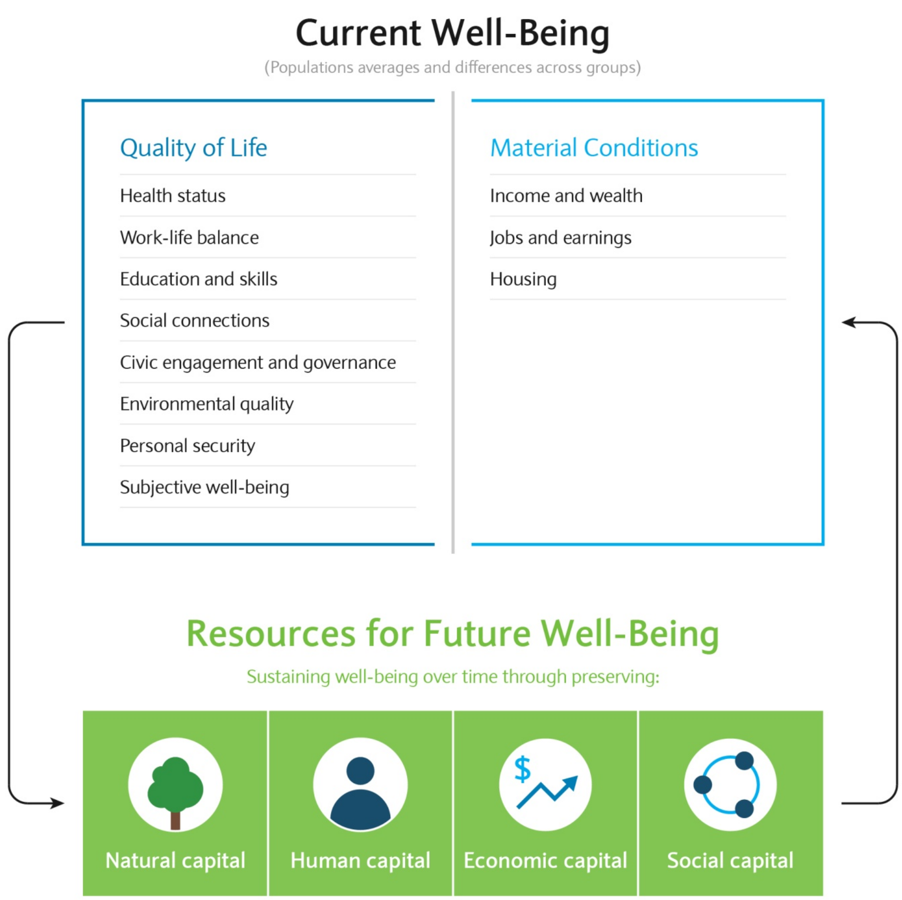
There is an ongoing discussion between economists and experts in statistical offices around the world about how to deal with some of the shortcomings of the traditional system of SNAs to help capture the new digital economy more accurately. Some technical progress will be made, without doubt. However, for practical and conceptual reasons (reproducibility of results, objectivity, transparency of methods, etc.), most statistical experts argue against the inclusion of reservation prices and shadow prices in official GDP measures in order to reflect the full welfare effects of digital products.[10] Given that it is this unmeasured consumer surplus where the economists see the largest effect, this is likely to leave lingering doubt about the appropriateness of the concept of GDP for a world transitioning from goods manufacturing to digital services.

This raises the philosophical question of what to include…

However, it also raises a more philosophical question: while the welfare gains from digital products are undoubtedly large, how many of these effects should be included in the core macroeconomic measure of GDP? Or should they instead be identified in data designed to gauge quality of life beyond GDP? Different measures may be needed for different policymaking purposes. Thus, a more promising approach could be a systematic attempt to capture the important dimensions of welfare and well-being in data sets that complement GDP and other macroeconomic aggregates (Figure 26).

FIGURE 26

Recent OECD initiatives aim at measuring societies in more comprehensive ways than GDP per capita

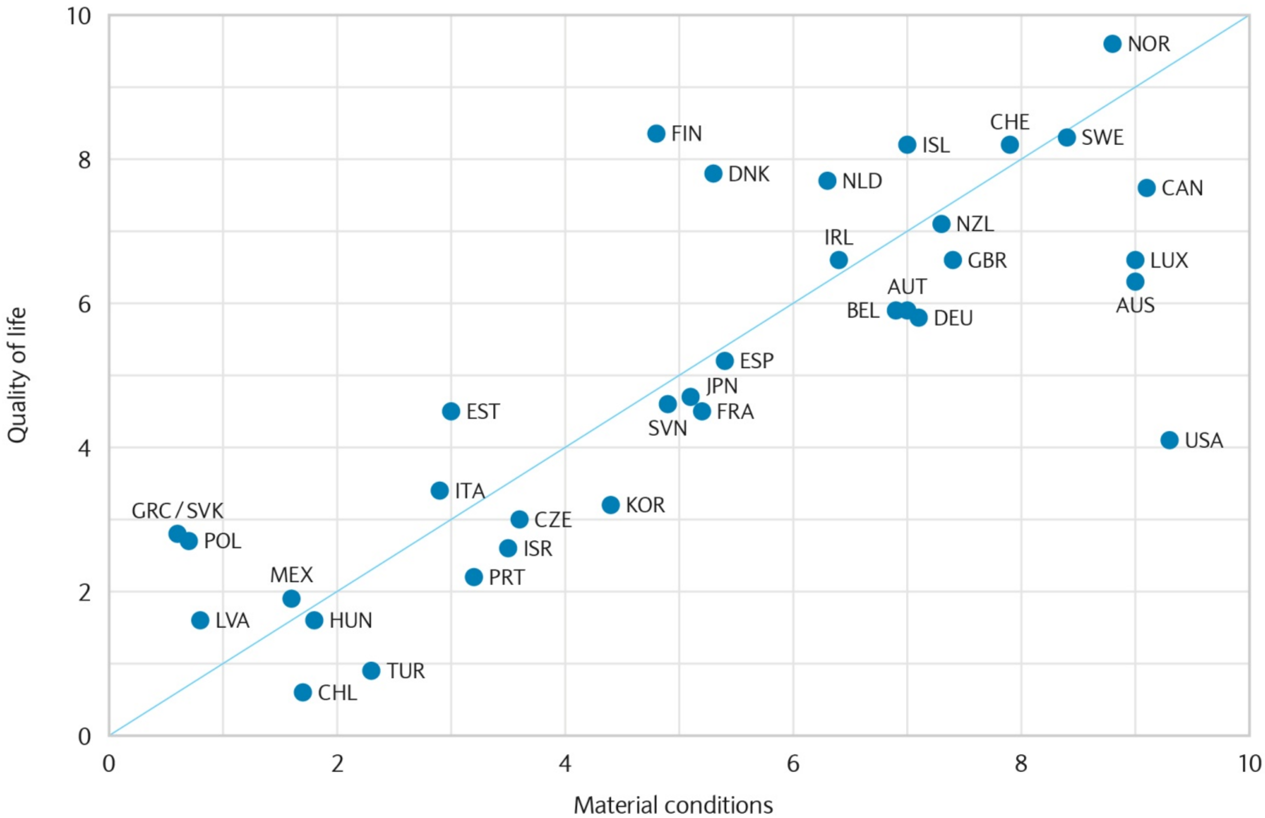


Source: OECD 2017

[10] For example, Reinsdorf and Schreyer (2017)

FIGURE 27

Material conditions and perceived quality of live can diverge significantly



Source: OECD 2017

…but any new measure of welfare will likely focus on quality of life as well

Moving beyond GDP requires indicators of well-being and welfare that cover the broader dimensions of life, economic and otherwise. A strategy taking into account the link between digitalisation and well-being should aim to assess the effects of digitalisation across the major dimensions of quality of life. These measures could be highly relevant for politicians and policymakers, even if not reflected in GDP or consumer price indexes. The OECD initiative to capture 'well-being' is going in this direction. These new measures show that countries' rankings for 'material conditions' and 'quality of life' often diverge materially (Figure 27).

Public finances: Focus on income support and taxing capital

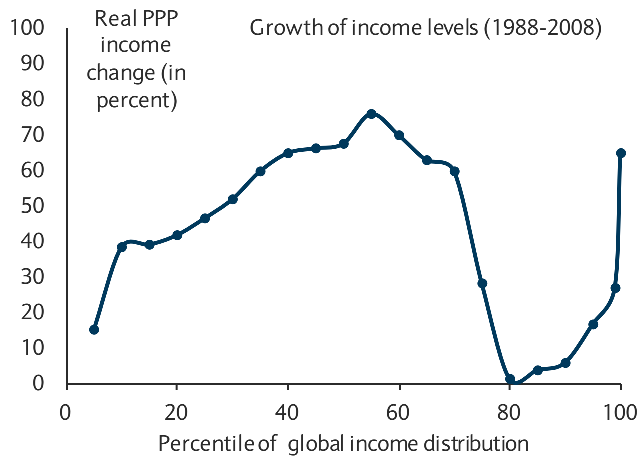
Globalisation lifted many EM citizens out of poverty…

… but led to stagnating incomes for DM middle classes

In *The Future of Globalisation*, we highlighted how global trade and the integration of emerging market economies in global value chains have led to dramatic changes in global income distribution. The so-called elephant graph measures the real income changes of different percentiles of global income distribution since the late 1980s (Figure 28). Its shape suggests that real incomes for populations in EM economies (main body) have improved significantly over the period, while those for middle income groups in advanced economies have stagnated (lower trunk) and the incomes for those in the top percentile have surged (upper trunk). Hence, while not benefiting everyone equally, globalisation has helped to lift the incomes of large segments of the world's comparatively poorer population.

FIGURE 28

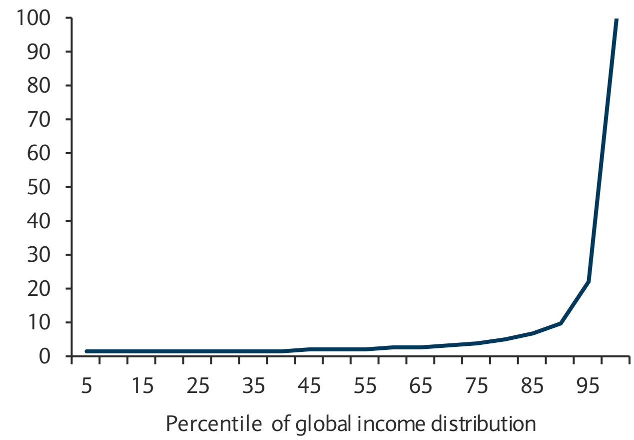
Could the 'elephant' chart over time turn into …



Source: Branko Milanovic (2012), Barclays Research

FIGURE 29

… a potentially more extreme distribution?



Source: Barclays Research

In the future, technology could distribute income gains increasingly to capital owners

This may no longer be true if the effects of technology rather than trade dominate in the coming decades. As automation creates pressure across global labour markets, future income gains could be concentrated in the very highest percentile of the global distribution. Indeed, Chinese manufacturing wages are already being pressured by automation in the same way that Chinese labor pressured US manufacturing wages in previous decades. If automation ends up playing an ever-greater role in workplaces, it could hold down wage growth in more parts of the economy, meaning that the labour share of income will continue to fall as the capital share rises. If, in parallel, capital ownership is concentrated further – also a trend of past decades, in part because of the 'winner takes all' tendency of the digital economy – income and wealth distributions could become extremely skewed. Expressed graphically and exaggerated for illustration, the elephant's bulky body would be flattened and all gains would shift towards the very tip of its trunk (Figure 29).

An abundance of economic output could be accompanied by rising inequality

Hence, policymakers could face a situation where technology facilitates rapid and cheap production of both physical and digital goods, but is paralleled by increasing measures of inequality and wage stagnation. This could fundamentally alter the criteria to assess economic policies. In a traditional production-based economy, the focus of 'good' policies was on improving productivity. In an economy where the highest productivity is achieved through the use of machines, distribution is likely to become a larger focus

Policy focus on helping workers transit between jobs and on compensating the permanently displaced

This greater focus on distribution may not necessarily mean *universal income,* a concept to which societies may react differently. While forms of permanent income support may play a great role at some point, the immediate challenges may be to educate and train humans to use new technologies as complements, rather than substitutes. If substituted nevertheless, retraining and transitional support will be key to helping workers adjust to new occupations. Put differently, policies need to ensure compensation for those displaced: economic theory never denied that structural change (eg, through free trade or new technology adoption) can create winners and losers, but it suggests that if the gains made by the winners are sufficient to compensate the losers' losses – ie, no one is worse off as a result – the change is for the better. However, such compensation, even if theoretically possible and required for the 'greater good', rarely takes place in practice. Future policy might need to play a bigger role in changing that.

Financing this expenditure could be a challenge

Financing such expenditures through revenue will be a challenge. A falling wage share in GDP and the 'casualisation' of labour (gig economy) make the taxation of labour income more difficult. Taxing individual robots or machines, as sometimes suggested, may be intuitively appealing (the robot replacing the human worker also as taxpayer), but makes less sense conceptually. Robots are assets of the owners of the overall capital. The challenge is, thus, to tax capital, which is typically difficult to maximise because of its high mobility.

Challenges for monetary policy

Central banks set specific targets to stabilize inflation

…and rely on interest rates to stabilize activity

In recent decades, many central banks have formally adopted a version of inflation targeting (IT) as their main monetary policy strategy. In simple terms, they set interest rates to lean against the business cycle and, hence, ensure that inflation returns to target. In an overheating economy, the central bank can increase interest rates to slow demand and ease price pressures. In a bust, it can reduce interest rates to stimulate demand to push the economy closer to full employment, thus raising price pressures. While not uniform and with different designs, central banks in advanced economies have generally set targets of 2% that they aim to achieve over the medium term.

Technology could challenge this strategy…

…via broken Phillips curves…

…which make activity less responsive to interest rates…

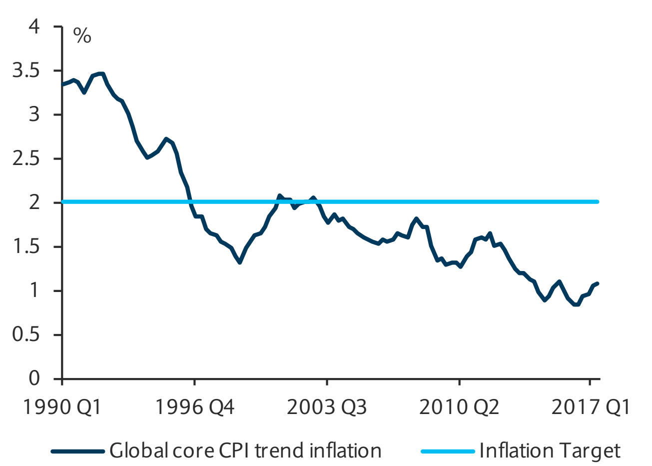
…and reduce the frictions that made 2% the right target

Technology challenges inflation targeting in several ways. The relationship between unemployment (capacity constraints) and wage growth (inflation pressures) – the Phillips curve – has been central to this mechanism. But competition from labour-saving technology could lead to weaker underlying nominal wage trends. This means that policy needs to stimulate activity more to get the same outcome. At the same time, the rise in wage inequality will likely make activity less interest rate sensitive, as richer households have lower marginal propensities to consume. In addition to challenging the policy transmission mechanism, technology may also raise doubts about the 2% target itself. A key argument for positive inflation has been nominal wage rigidity, ie, workers would be resistant to taking nominal wage cuts. Real wage cuts through inflation would thus grease the wheels of the labour market. But the rise in labour market flexibility and allocative efficiency due to technology may make this unnecessary. In addition, economists (eg, Tobin) typically highlight that some inflation is needed to allow for real price adjustments, including to wages, without reducing nominal wages. This seemed true in a world of sector- or even nationwide wage bargaining through unions, where it seemed psychologically impossible to agree on a nominal reduction. In today's world of more flexible and fragmented labour markets (the gig economy), this assumption may no longer reflect reality.

Finally, minimum inflation was deemed necessary to allow the real interest rate to go potentially below zero, given that a zero nominal interest rate was deemed the lower bound. However, negative interest rate policies over the past years have shown that the lower bound may not be zero, but possibly minus 100-150bp – or roughly what is deemed the

FIGURE 30

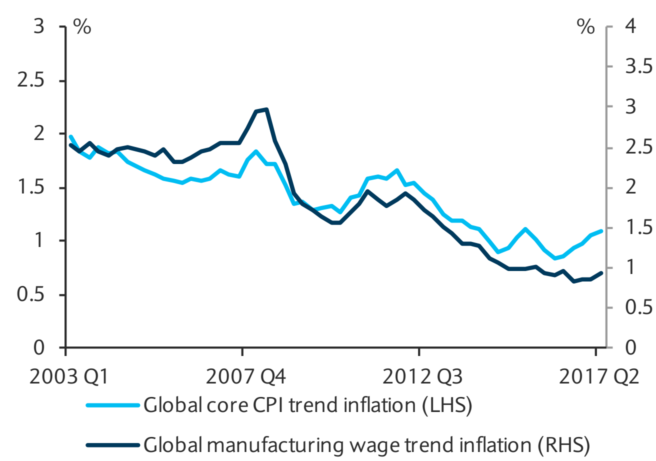
Global core CPI trend inflation is significantly below target…



Source: OECD Main Economic Indicators, Barclays Research

FIGURE 31

…as a result of weak manufacturing wage trend inflation



Source: OECD Main Economic Indicators, Barclays Research opportunity cost of holding cash – and in the future it may be even be lower: in a cash-free economy with central authority, negative interest rates could in principle go lower still.

Inflation remains a monetary phenomenon, but technology may make calibrating policy to reach 2% more difficult

In sum, the traditional arguments for a certain rate of positive inflation may not be invalid but have at least become less compelling. While Nobel Laureate Milton Friedman's famous statement that 'inflation is always and everywhere a monetary phenomenon' may hold in principle, calibrating policy to achieve a 2% target precisely could become more difficult, as a host of central banks have discovered over the past few years. If this assertion is correct, it is not clear if central banks should continue to follow inflation targeting frameworks with the current specifications.

We estimate global core CPI trend inflation at just over 1%

…driven by lower global wage trend inflation since 2003

Our own estimates of global core CPI trend inflation (first discussed in *The fight to bring back inflation*) suggest that the underlying trend in inflation has fallen significantly over time to reach 1.1% today. This occurred despite significant monetary policy easing in recent years, which suggests that powerful secular trends likely contributed to the weakness in inflation (Figure 30). Indeed, Figure 31 suggests that, at least since 2003, global manufacturing wage trend inflation is perhaps responsible for this secular decline in core CPI inflation. If manufacturing employees are happy to accept stagnating wages because of fear of being substituted, then monetary policy will have a difficult time stimulating inflation, as suggested by the recent situation in Japan, where workers shortages have translated into lower output rather than higher wages.

If central banks, despite these secular trends, try to push inflation to 2% at all costs…

…financial instability could be the unintended result

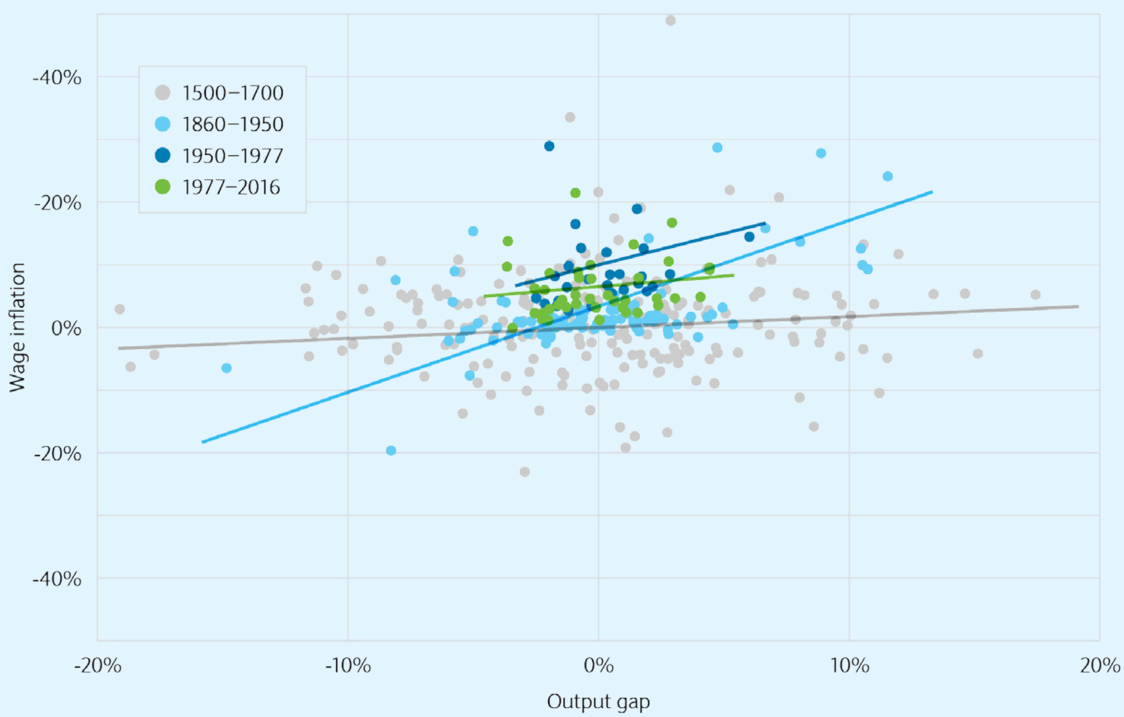
If technology reduces the real effect of monetary policy and leaves the optimal inflation target below 2%, pursuit of the 2% target risks creating financial cycles and instability. Friedman's monetary phenomenon would certainly occur somewhere, but perhaps in financial markets or in specific sectors of the economy, eventually leading to sector boom-and-bust cycles. To avoid exacerbating the business cycle, we therefore believe that prudent central banks may want to adopt a greater degree of flexibility, such as the introduction of bands around their inflation targets.

Box 3: The nature of work and the flatness of the Phillips curve – back to the future?

Technology is also fundamentally changing the nature of work and employee-employer relationships. Technology has made work is increasingly 'divisible', separating work processes into many parts. This facilitates automation and the potential substitution of human labour. But it has made the remaining parts of human to become more flexible: the jobs done by humans may no longer have to be performed at a certain location at a certain time within strict formal arrangements. As jobs become less structured and more task-oriented, there has been an increase in self-employment, part-time working and special contractual arrangements (e.g. zero-hours contracts). This is often referred to as 'casualisation' of work, or 'gig' economy.

This creates a very different environment for wage negotiations than the union-dominated bargaining processes that were typical for the 20th century. Certainly, critics may argue that such new, less formal arrangements may be sought by employers simply as a means to reduce costs. But they also do seem to clearly reflect a desired flexibility on the part of many of those who seek work, in particular among younger workers and those who have not participated in the labour market under traditional formal employee relationships. As Andy Haldane (2017) notes, this change in the nature of work could in some ways be interpreted also as a shift 'back to the future'—a world where artisanal and task-based jobs may more resemble the pre-industrial revolution era, when most workers were self employed and worked in small businesses.

The available historical wage and output data are of course partial and imperfect, but they nonetheless tell an interesting story: when constructing UK Phillips curves over four periods – 1500-1700 (pre-Industrial Revolution), 1860-1950 (post-Industrial Revolution), 1950-1977 and 1977-2016 (post-war period) – only the two post-war Phillips curves conform to what economist consider 'typical': only the 1950-1977 and 1977-2016 curves have a clearly positive slope (less slack in the economy is associated with higher wage inflation) and an intercept that is positive (reflecting positive trend inflation), where by the more recent curve (1977-2016) is clearly flatter. In contrast, the post-Industrial Revolution (1860-1950) has also a positive slope but has an intercept associated with an average inflation rate of around zero. The latter is also the case for the pre-Industrial Revolution curve (1500-1700), but in addition, this one is also almost entirely flat. This shape – a flat slope with an intercept suggesting zero average inflation – most closely resembles the Phillips curves operating in the more recent past. Certainly, this similarity may be explained by a number of factors—not least the questions one may have around data from before 1700. However, the pattern supports the narrative that technology changing nature of work and the related process of wage formation: away from formal, structured relationships with collective wage bargaining, towards a more flexible, divisible, individualistic workforce, which leads to a flatter Phillips curve relationship.



Source: Haldane (2017), Thomas and Dimsdale (2017)

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