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GDP: a digital remix

How official statistics understate growth and overstate inflation

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Preface

The aftermath of the Global Financial Crisis has reinvigorated the debate about the shortcomings of mainstream neoclassical macroeconomics. Yet strangely, much of the profession has remained in denial, hankering for a return to 'normal' and carrying on with its old models. In this report, we challenge this outdated approach and repeat our call for a radical rethink on how we measure and forecast economic growth. The need to rework macroeconomics has become ever-more urgent.

We see three crucial lessons that need to be learnt from the last decade. First, **economies are not self-correcting**. The fact that the recovery of the past few years has been achieved only by dint of unprecedented and unconventional policies is testimony to this. Meanwhile, explosive growth in new digital technologies is leading to disruptive changes in business and behaviour that make a mockery of the idea that we will revert to some kind of stable equilibrium.

Secondly, **balance sheets matter**. Macroeconomic models that focus on the flows of income and spending ignore the critical role played by the wealth effects arising from the financialization of the global economy. Indeed, most models barely even incorporate the financial sector, let alone recognise that banks create money by making loans. They therefore fail to capture the vulnerability of economies to setbacks in asset prices, which render growing debt loads unserviceable. Nor are they well equipped to assess the systemic effects of the combination of massive asset purchases by central banks and sweeping changes to financial regulation, the consequences of which will not be clear until the next recession strikes.

Thirdly, **distribution matters**. The fact that the rich disproportionately benefited from globalisation and new technologies, not to mention the successful efforts of central banks to boost equity and bond prices post 2009, has arguably been a drag on growth. But what is unarguable is that it has played into the hands of populist and nationalist politicians. This is corroding the previous economic policy consensus of fiscal probity, independent monetary policy, free trade and liberal movements of capital and labour.

Sadly, the macroeconomics profession has yet to come to terms with these lessons. A new consensus on how to predict and manage the macroeconomy has yet to emerge. It is time for economics to be remastered.

To meet this challenge, we believe it is essential to address the fundamental flaws in how the economy is measured. At the heart of this are the statistics for Gross Domestic Product (GDP), which remain the key target of economic policy around the world. Despite repeated methodological changes, they remain deeply, and crucially, *increasingly* flawed.

In seeking to 'remaster' GDP, this report examines ways to fine-tune or 'remix' its composition. We will pay particular attention to the rapid digitalisation of the economy that has been gathering momentum over the past 25 years. We stress that its impact in boosting output and reducing inflation is inadequately captured.

We would like to acknowledge the special contribution of John Calverley, who collaborated closely with us in conducting much of the underlying research and writing of the report. We also received valuable input from members of the ING Global Research team and a number of outside experts, most notably Professor Diane Coyle, whom we cite among our references. As usual, we remain responsible for any errors or omissions.

Mark Cliffe

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Executive Summary

Gross Domestic Product is the revered measure of the size, and success, of national economies. Although it is commonly thought of as reliable and objective, it is a complex statistic with a history of errors, controversies and changing methods and definitions. In seeking to 'remaster' GDP, this report examines ways of fine-tuning its composition. We pay particular attention to the impact of the rapid digitalisation of the economy that has been gathering momentum over the past 25 years. Pursuing the music analogy, our focus is on a digital remix of GDP.

- On conservative assumptions, we believe official data **understates US GDP growth by 0.75% per annum** and **overstates inflation by 0.4%** due to inadequate measurement of the digital economy and the exclusion of investment in certain intangibles.
- We calculate the **under-measurement of the digital sector to be about 0.5% of GDP** annually, which arises because of rapid price declines, the plethora of new goods and services and the extent of free goods. The improvement in quality is significantly under-measured so that output is understated and inflation overstated.
- Mis-measurement of the digital sector may go back 30 years or more but is likely an increasing problem as it becomes more pervasive in the economy.
- Correctly accounting for all **intangibles** by including them as investment would add **0.25%** to GDP annually. Intangibles still left out by US statisticians include investment in brands, some types of intellectual capital, training, and the value of a firm's organisation and structure.
- The under-measurement of GDP is probably even greater than the 0.75% p.a. we claim, perhaps 1% annually or even as much as 2% because of the growing importance of **services** in general, where the calculation of quality improvements is much harder than for manufacturers.
- US trend growth has slowed by about 1.1% p.a. since 2004, according to official figures. As much as half of this may be explained by mis-measurement in the digital sector and intangibles. However, not all of the slowdown can be explained in this way because some of the mis-measurement we find occurred prior to 2004.

How much mis-measurement?

% p.a.	Nominal GDP	Inflation*	Real GDP
What's left out			
Intangibles	↑↑ 0.25	≈ no est.	↑↑ 0.25
Free goods	↑ 0.1	≈ no est.	↑ 0.1
Sharing economy	≈ no est.	≈ no est.	≈ no est.
Mis-measurement of the deflator			
Quality change in digital products	≈ no est.	↓↓ -0.2	↑↑ 0.2
Digital products replacing non-digital ones	≈ no est.	↓ -0.1	↑ 0.1
Improved variety due to digital platforms	≈ no est.	↓ -0.1	↑ 0.1
Late inclusion of novel digital products	≈ no est.	↓ no est.	↑ no est.
Bundling in digital products	≈ no est.	↓ no est.	↑ no est.
Outlet substitution bias	≈ no est.	↓ no est.	↑ no est.
Quality improvement non-digital services	≈ no est.	↓ no est.	↑ no est.
TOTAL**	↑↑ **0.35**	↓↓ **-0.4**	↑↑↑ **0.75**

Data: percent, year-on-year.
*GDP deflator. Consumer prices may differ slightly.
** of items where estimates are available.

Introduction

Although GDP is commonly thought of as a reliable and objective benchmark, it is deeply flawed

Gross Domestic Product, GDP, is the pre-eminent economic statistic. It is the revered measure of the size, and success, of national economies. It has become the key target of economic policy, pored over by governments, economists, businesses and financial markets to make policy and investment decisions, and by people judging who to vote for. But it is also deeply flawed. Although it is commonly thought of as a reliable and objective benchmark, it is a complex statistic whose history is strewn with errors, controversies and changing methods and definitions.

Governments wanted a measure that could guide fiscal policy, so the focus settled on market-based activities

Simon Kuznets, who shaped the creation of the modern ways of estimating national income in the 1930s, originally advocated that the goal should be to measure welfare rather than output, spending or income. But he lost out for practical measurement and pragmatic policy reasons. Governments wanted a measure that could guide fiscal policy, shaping their tax and spending decisions. The focus therefore settled on market-based activities, based on final goods and services to avoid the double-counting of intermediate inputs like raw materials. National production was carefully defined to equate with national income and national expenditure.

Yet non-market activities contribute to welfare, and some market activities do not: think of pollution...

...and there have been many subjective changes in its definitions, such as including government and finance

Yet non-market activities contribute to welfare, and some market activities do not: think of the negative side effects of production such as pollution, for example. Nevertheless, this has not stopped GDP being widely used as a measure of welfare. Moreover, the attempt to portray GDP as a purely objective measure of national output rather than a subjective measure of well-being glosses over the fact that normative judgements about its evolving definition have been made all along. Notably, services from government, and later financial services, were added into the definition of GDP as they were eventually deemed to be productive and valuable.

Another major problem is how to account for inflation

Another major problem has been how to account for inflation. Nominal GDP can be boosted by rising prices so to calculate the volume of output, prices need to be accurately measured. This is a complex task, because the mix and features of products and services evolve. Originally statisticians ignored this, but over time they have started to employ 'hedonic' adjustments to allow for quality improvements. The example of mobile phones, which are unrecognisable from those of 10 or 15 years ago, illustrates the challenge. And in making quality adjustments, statisticians are making a distinction between market prices on the one hand and value, and hence well-being, on the other.

"Aside from the fact that market prices don't readily equate with perceived value, GDP is a flawed measure of welfare in several other ways. More money does not always make people happier"

Aside from the fact that market prices don't readily equate with perceived value, GDP is a flawed measure of welfare in several other ways. More money does not always make people happier, in part because they care about their status (people may be content with less money so long as they have more than others). This means that the distribution of GDP, and not just its total, also matters for national welfare. The distinction between work and leisure is not as clear-cut as it first seems: people also derive pleasure from work and do unpaid work[1].

Another problem is that GDP does not take account of future prosperity. If current output comes at the expense of future output, then future welfare may be jeopardised. Statisticians do calculate Net Domestic Product (NDP) by accounting for depreciation

[1] Welfare implications are beyond the scope of this report, but research led by E. Brynjolfsson proved that digital goods have created large gains in well-being that are not captured by the conventional measures of GDP. Moreover, D. Coyle and L. Nakamura suggested to look at the implications for welfare through the lens of time use.

(wear and tear) of physical assets, but this is only part of the story. To get a fuller picture of the sustainability of economic activity, we would also need to take account of investment in human capital and the adverse effects of resource depletion.

If it is true that 'you manage what you measure', as the old adage suggests, these GDP flaws are particularly troubling, as they are liable to distort government policy and economic decisions[2]. And if we accept that GDP is not a measure of welfare, whose interest is it serving? Can GDP be remastered to make it more relevant?

But the problem is that there is no ready-made alternative. Or rather, there are many alternatives, but they all have their own drawbacks...

The problem is that there is no ready-made alternative. Or rather, there are many alternatives, but they all have their own drawbacks. Some of these are conceptual: what are we trying to use it for? To measure household welfare? Or to capture the change in sustainable national wealth? Other drawbacks are practical: do we have the right data? Are we missing forms of capitals, intangible but also natural capital? The latter, in particular, keeps the UK's Office for National Statistics rather busy. But at least GDP has an established infrastructure of statistical collection, and its market focus at least makes it useful for the government's fiscal decisions.

...and some economists doubt whether distortions in GDP are getting bigger

Moreover, while GDP may be distorted in various ways, some economists doubt whether these distortions are getting bigger. So, they argue, while GDP may be flawed, it's still the best indicator of national prosperity that we have. While there is little sign that GDP is likely to lose its crown as the leading economic statistic anytime soon, we do believe that its flaws are growing, and that other alternatives, perhaps a suite of alternatives, is needed.

Like corporate performance, the economy perhaps needs a suite of indicators

Here we would use the analogy with the growing range of indicators for corporate performance. Plain vanilla quarterly and annual profit figures now come in a wide variety of flavours and are supplemented by a range of indicators of performance and balance sheet health. Companies are increasingly responding not just to their shareholders, but also to the interests of employees, customers, and broader society.

In seeking to 'remaster' GDP, we will examine several ways in which its tune could be remixed

So in seeking to 'remaster' GDP, we will examine a number of ways in which its composition could be fine-tuned. In this report, we will pay particular attention to the impact of the rapid digitalisation of the economy which has been gathering momentum over the past 25 years. Pursuing the music analogy, our focus is on a digital remix of GDP.

Econgloom vs. Technophoria

The digital economy has raised profound new doubts over the credibility of GDP...

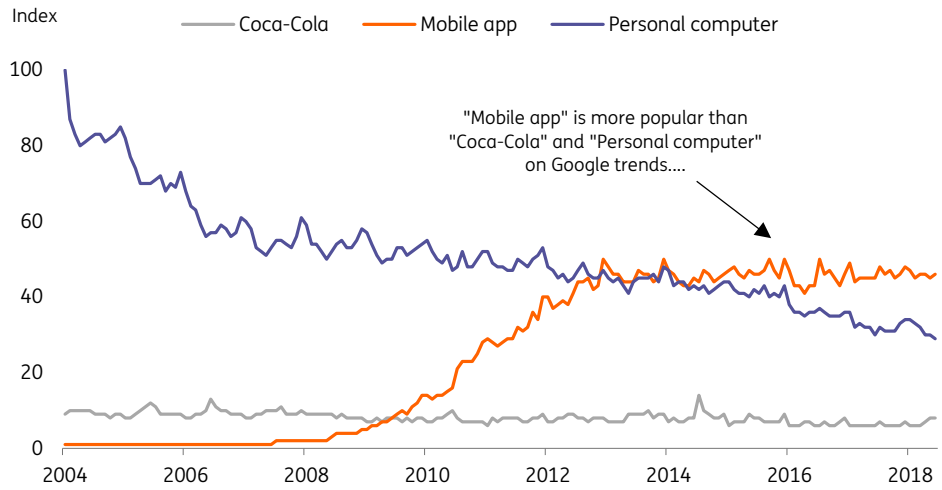
Over the last few decades the definition and measurement of GDP have evolved to address perceived problems and changing circumstances. However, the emergence of the digital economy has raised profound new doubts over the credibility of GDP statistics and triggered a more urgent search for better measurement.

...as the range of digital products and services explodes

Life has been transformed by digital products and services in the last 30 years. Social media, messaging, streaming and thousands of other apps have proliferated. Innovation continues with huge investments in big data, artificial intelligence, robotics and the internet of things (IOT). Businesses everywhere are braced for disruption while 'Big Tech' now dominates the US stock market.

[2] The flaws of GDP also remind us of the another adage: 'Not everything that counts can be counted, and not everything that can be counted counts.'

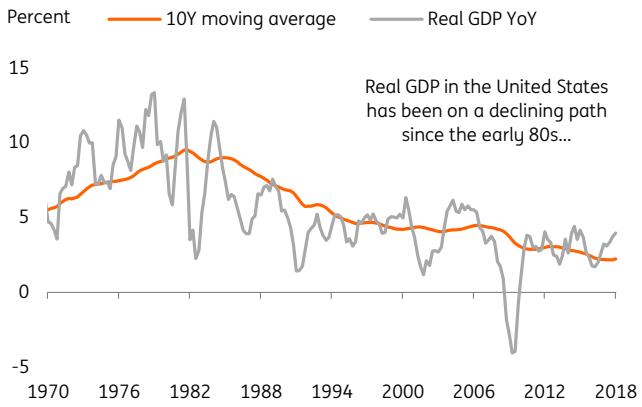
Fig 1 'Mobile apps' have dethroned popularity of traditional brands and products



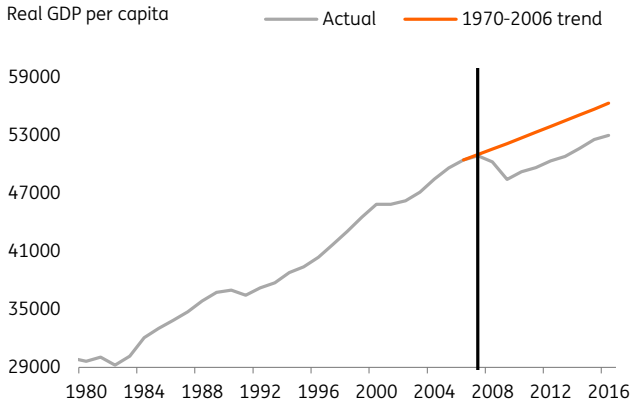
Data: popularity is measured as the relative number of searches on google trends. Region: worldwide.
Source: ING, Google Trends

Yet official statistics suggest that productivity and 'trend' GDP growth have slowed in the last decade and we are told that median living standards are little higher than 10 years ago in many advanced countries or even 20 or 30 years ago in the United States.

Fig 2 US Real GDP growth has been declining since the 80s...



...while US productivity growth took a hit following 2007....



Source: ING, Macrobond

People are pessimistic about the future

Concerns over weak GDP growth have triggered a wave of pessimism about the future. Around 70% of respondents to the Pew Survey from Europe, the US and Japan say they expect their children to be financially worse off than their parents (Pew 2017). Oddly, this pessimism does not match with what people say about their current situation. In the US for example, the Federal Reserve Survey of household well-being finds that only about 22% of people report that they are financially worse off than their parents at the same age (Federal Reserve 2016). Over half reckon they are better off and about a quarter the same. People aged 18-29 are only slightly more downbeat than older generations. So, is the official pessimism about recent trends in GDP triggering an unnecessary popular pessimism about GDP?

Is GDP capturing the incredible improvement in quality of the online experience since the early days of dial-up modems – the speed of page-loading, the massive amount of content, including new user-generated content and the availability of streaming? How can GDP measure things which cost nothing, like a Google search or reading a Facebook post? Is GDP really capturing the value of smartphones which bundle together a phone, camera, GPS and maps, web browser, music player, game player and much else all in one product? And what about the effects of digital platforms like eBay, Uber and Airbnb?

Calculating GDP: The two big challenges

Is everything relevant included? And how much of the nominal increase is due to higher prices or real growth?

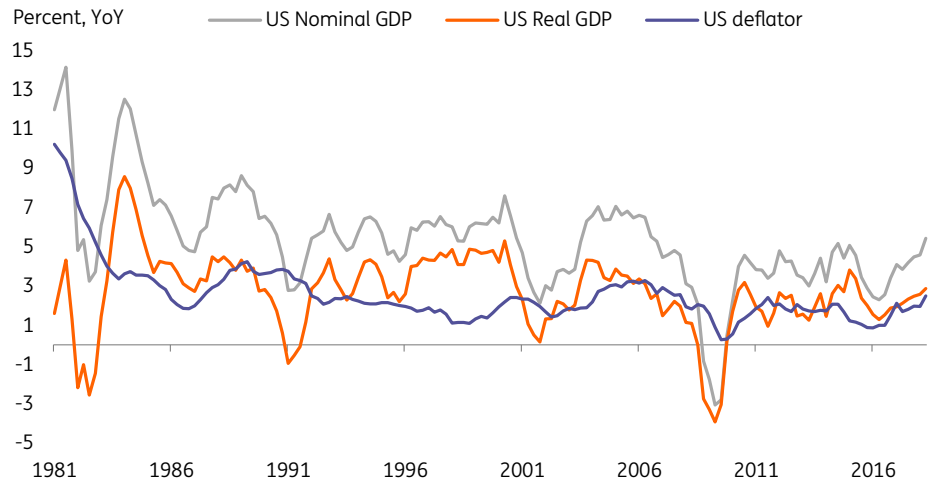
GDP is the total value of final goods and services produced and sold over a given period of time. As such, it values output at market prices. However, what is often overlooked is that the definition of GDP has changed radically over time as the economy has evolved and statisticians have modified their methods[3]. This reflects two key challenges:

- **The first challenge** is to make sure that everything relevant is included. The digital era has thrown up important questions about how to deal with 'free goods' like social media or Wikipedia, as an example. Although from the outset GDP was not intended as a measure of welfare, many revisions to it over the years have been justified on welfare grounds, notably to adjust for quality improvements.
- **The second challenge** is how do we know how much of the increase in money, or nominal, GDP is due to higher prices or to so-called real growth? Statisticians need to calculate a price index, called the GDP deflator, measuring the average change in prices across all the goods and services. It effectively 'deflates' the increased nominal value of GDP to estimate the real increase. Calculating deflators has always been difficult because goods change over time. But in the digital era this problem has become particularly acute because the price of most digital goods has been falling fast while their capability has been advancing rapidly.

Growth and productivity have been understated and inflation overstated

In recent years, officially measured productivity and therefore GDP have been growing slowly. So our claim that GDP may be under-measured by 0.75% p.a. is the equivalent of saying that output per worker has been growing 0.75% faster than measured. And some of the under-measurement is caused by an overstatement of inflation.

Fig 3 Growth in US nominal GDP, real GDP and inflation since 1980



Source: ING, Macrobond

Services versus goods

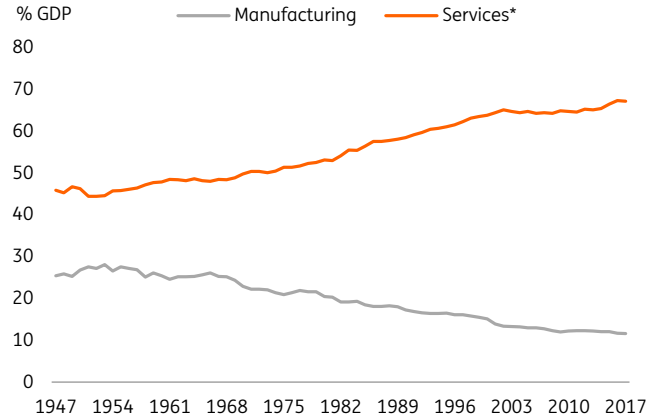
When GDP was created in the 1930s, services accounted for about half of GDP. Today they are around 80%...

GDP has always been better at measuring growth in the manufacturing sector than in the services sector. The problem is how to measure changes in quality. When GDP was first created back in the 1930s, services accounted for about half of GDP. Today they account for around 80% of the economy in advanced countries. In his 1994 Presidential Address to the American Economic Association, Harvard University economist Zvi Griliches divided GDP into 'easy to measure' industries vs 'hard to measure' industries

[3] For accessible accounts of this, see 'GDP' by Diane Coyle and 'The Value of Everything' by Mariana Mazzucato.

(Griliches 1994). In the easy category he placed agriculture, manufacturing, transport and information. It is relatively easy to count and value food and manufactured goods output and passenger miles for example. In the hard category, he placed financial services and real estate, professional and business services and education and health.

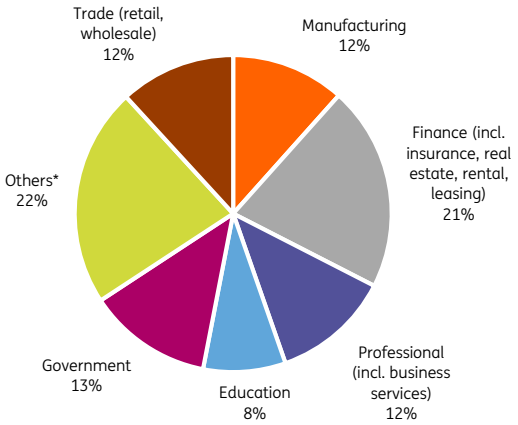
Fig 4 The changing composition of US GDP



*"services" includes: wholesale trade; retail trade; transportation and warehousing; information; finance, insurance, real estate, rental and leasing; professional and business services; educational services, healthcare and social assistance; arts, entertainment, recreation, accommodation and food services; *other services, expect government. Government not included.*

Source: ING estimates on BEA data

Fig 5 Composition of US GDP as of 2017



"others" include Agriculture, forestry, fishing and hunting; mining; utilities; construction; transportation and warehousing; information; arts; other services except government.

Source: ING estimates on BEA data

These hard-to-measure items are likely to be systematically under-estimated. **We think that much of the GDP measured is based on extremely tenuous data**. As an example, trade data is some of the worst, although statisticians use conservative assumptions in this area because they are wary about producing figures which lack a strong justification.

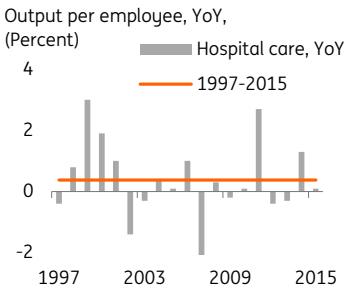
Statisticians report significant productivity gains in some service areas....

This is not to say that the statisticians don't report significant productivity gains in some service areas. US data, for example, records annual growth in output per hour from 1997-2007 of 7.7% in travel arrangements and reservations, 4% in commercial banking and 3.8% in medical diagnostic labs. Wholesale and retail trade productivity also grew rapidly over the same period, at 3.8% and 3.9% p.a., respectively. But measuring growth in the services sector takes extra analysis and resources which are not always available.

But measuring is tricky...housing consumption is based on assumptions about 'imputed rents', not real transactions

Housing is a good example of the problem facing statisticians. In the current version of GDP, housing consumption includes spending on rented accommodation. It also includes an estimate of the value of the benefit homeowners receive from living in their own home. Otherwise a shift from renting to owning would distort GDP downwards. So homeowners are deemed to be receiving 'imputed rents. These are not real market payments, but rather statistical assumptions to ensure that all consumption of housing is included in GDP.

Hospital care productivity not adequately captured?



Source: Feldstein, 2017

Similarly, financial services were for a long time excluded from GDP. In other words, they were deemed to be unproductive. For a long time, interest payments were regarded as a cost of doing business. It is only in the last 20 years or so that the gap between the banks' lending rates and their cost of funds came to be defined as 'financial intermediation' and part of GDP (Coyle, 2014). Suddenly, finance became a big part of GDP **(see Fig 5)**.

Another widely debated category is hospital care (Feldstein 2017). The official statistics show output per employee up just 0.4% p.a. from 1997-2016. But it is doubtful whether these statistics adequately capture improvements in surgical techniques and patient recovery processes, which have reduced the length of patient stays. There are even more questions about the digital area, which is the principal focus of this paper.

Official statistics suggest that average US productivity growth slowed from 3.4% p.a. during 1955-75 to 2.8% p.a. in 1975-2015. But if we assumed for a moment that the average deflator for the hard-to-measure categories was actually the same as the easy categories over the whole 60 years then the productivity slowdown post-1975 becomes less obvious.

In the mid-20th century when higher productivity was achieved by automating factories and scaling up production lines with bigger, faster machines, it probably did make sense. But in the digital era, productivity is rising because of faster data processing, zero-cost copying and instant access to information. These processes can raise productivity in services as much as manufacturing.

The first challenge: what's left out?

Intangibles

Much spending on intangibles is included as an intermediate expense and not counted as investment spending

While GDP is good at measuring the value of tangible things like factories and machines, statisticians struggle with intangibles, namely investments which are not physical by nature. The problem for the statisticians is how to put a credible number on that spending. Tangible investments are visible and often have a market value but intangibles often do not. So instead, much spending on intangibles is currently included with all the rest of the firm's spending as an intermediate expense (a cost) and not counted as investment spending. If it were added to investment as it should be, it would add to GDP too, by up to 0.3% p.a..

Intangibles and US statisticians

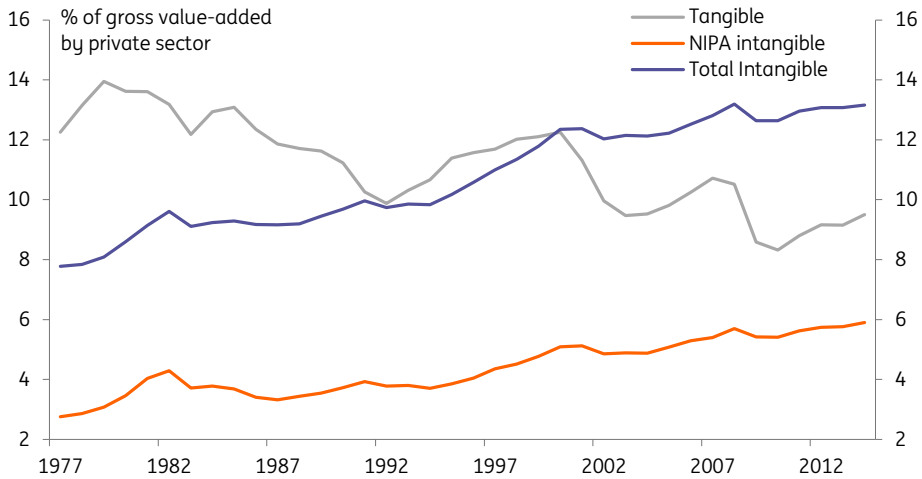
US statisticians have added categories of intangibles into GDP, but still leave a lot out

In the US, statisticians have been gradually adding categories of intangibles into investment (and therefore GDP), but still leave a lot out. Software and mineral exploration were added in 1999. Then in 2013, scientific R&D spending as well as intellectual property in entertainment, such as movies and books were added. This last change brought a one-off 3% rise in GDP. But US GDP still does not capture investments in brands, non-scientific R&D, training and organisational capital.

One study found that if all intangibles were treated as investments, US business investment would be much higher, and would not have declined

One study found that if all intangibles were treated as investments, US business investment would be much higher than thought and, interestingly, would not have declined, as suggested by the official statistics (Branstetter 2017). Instead it would have been fairly stable over the last 40 years at about 20-22% of GDP. Rather than being about two-thirds tangible and one-third intangible, however, the balance has shifted to about two-thirds intangible **(Fig. 6)**.

Fig 6 Tangible and intangible investment as % of total value added by the private sector in the United States, 1977-2014



Source: Branstetter, Sichel (2017). Update to Corrado et al. (2012) provided by Carol Corrado.
Note: Tangible investment excludes intangible assets included in the GDP accounts, such as software and research and development. The total intangible share is adjusted by adding the additional intangible output to the denominator as well the numerator.

An earlier study estimated that if all investments in intangibles were included, non-farm business sector output would be 17% higher (Corrado, Hulten, Sichel 2006). The non-farm business sector accounts for 75% of output so this would raise GDP by about 13%. Since then, the inclusion of more intangibles has raised official GDP but there is likely a further 7-10% that could be added. This will have been accumulated over several decades but could potentially add 0.2-0.3% p.a. to official estimates of GDP growth.

Investment in intangibles has been accelerating

It seems likely that investment in intangibles has been accelerating in the digital era. Within the ITC sector itself, most of the value is in the intangibles – the software, the data, the value of the platform etc. But digital technology has vastly increased the importance of intangibles in the rest of the economy, too. Firms have their own data, often their own software and they are using big data techniques to enhance their knowledge of customers as well as improve their production processes. They also use social media to help build their brand. Building a platform through rapid loss-making expansion, like Amazon or Uber, is itself a huge investment in brand. As big data and artificial intelligence develop, spending on intangibles is set to become even more important.

If investment has not declined, one of the most plausible explanations for 'secular stagnation' is removed...

The higher rate of investment recorded when intangibles are included throws doubt onto the apparent slowdown of GDP in the last decade. Many economists have talked of 'secular stagnation' meaning a prolonged period of negligible growth, predominantly affecting advanced economies. One of the common explanations for the slowdown is lower investment. But if investment, properly measured, has not declined, one of the most plausible explanations for the slowdown is removed.

...although "leaders" in the corporate world may have gained at the expense of "laggards"

On the other hand, the rise of intangibles could offer another explanation for secular stagnation. For example, Haskel and Westlake argue that industries with a strong concentration of intangibles could have a general tendency to foster the emergence of "leaders" and "laggards" (Haskel 2017). Here, leaders are industry titans very good at scaling up positive spillovers from other platform companies, while laggards are smaller firms which are typically less efficient at scaling up external positive spillovers and therefore are more reluctant to invest in intangibles which ultimately could benefit only the "leaders". Under this assumption, leaders would continue to invest but not strongly enough to compensate for the laggards' reluctance. These two factors combined give rise to a lower aggregate investment in the economy and therefore offer an alternative explanation to secular stagnation.

Inadequate capture of intangibles in the supply chain

GDP measurement may not be keeping up with how companies charge for intangibles

A related problem is whether GDP measurement can keep up with the way companies charge for intangibles. For example, the US may include the full value of phones as imports from China but there is no measure of the export of US knowhow included in the phone. The royalties are often routed through low tax jurisdictions such as Ireland or Luxembourg. As our trade team argued in a recent report, US exports could be under-estimated while US imports from China could be over-estimated.

Free goods

Many digital goods are free at point of consumption but they are not entirely free

Many digital goods are free at the point of consumption. Search, maps, social media, Skype, messaging, taking photos, as well as some games, music and video are effectively free at the point of use. But they are not completely free. You need a computer, smartphone or tablet as well as Wi-Fi or data and these involve costs, mostly fixed costs, though they may be variable to some extent (e.g. extra data or faster broadband). But the variable costs are small relative to the content received. In some cases, access to content requires consumers either to view advertisements and/or give up personal data. This can be considered a 'barter' relationship where two agents exchange things without money changing hands.

Most studies conclude that it is hard to find a way to add free goods into GDP

So are free goods included in GDP? Plainly they do not show up as market goods and services because there is no money changing hands. Spending by companies on advertising and data is treated as an intermediate input (like the intangibles discussed above) so it will be included in GDP, but indirectly via the cost of the things people buy.

Can we add free goods back into GDP?

One study found it would add about 0.11% p.a. to US GDP growth from 2005-15

How much would it change GDP if we better accounted for free goods? One study treated the provision of free content as a transaction: consumers receive content in exchange for exposure to advertising or marketing (Nakamura 2017). In effect it said let's treat households as active producers of 'viewership services' that they exchange for consumer entertainment. The study found it would add about 0.11% a year to US GDP growth from 2005-15 or 1.1% in total. This is significant, just about, but quite small. One of the reasons is they allow for the decline in newspaper and other media advertising. Another is that, fundamentally, it is not very expensive to create all the free content we enjoy, especially because much is user-created.

To get a feel for this calculation consider the revenues of Google and Facebook. Their combined global revenues in 2017 were about $150 billion according to their annual reports. US users account for less than a fifth of total Facebook users and even less for Google, but revenues from US users will probably be much higher than the average. If we (generously) suppose that two-thirds of these companies' global revenues from advertising and data derive from US users, this would be about $100 billion. This is a sizeable sum but only 0.5% of GDP, which is over $20 trillion. If we assume that those revenues built from nothing over 10 years this gives us about 0.05% p.a. extra GDP. There are other companies providing free goods of course, though these two are the largest. If we could add them all up and total $200 billion in US revenues we would be in line with the estimate in the paper above.

Another study by statisticians at the OECD tried to measure the value of Facebook[4] by considering how much people would pay not to have to give up their data (Ahmad 2017). The authors used various assumptions but the largest estimate came out at just $22 billion for the US ($178 billion for the world). Despite concerns about people giving up data, most consumers don't seem to value it very highly. One German study found that people valued their personal data at only about 1 euro a month (Beresford 2017). They deduced this by setting up two websites offering identical DVDs on line. The difference was that one website required users to supply personal information like date of birth. When the two websites charged the same price, they had a similar number of sign-ups suggesting people did not care very much. When they reduced the price on the website asking for sensitive data by just 1 euro it took most of the business.

Most studies conclude that it is hard to add free goods into GDP. We can probably add no more than 0.1% p.a. to GDP growth. Digital goods are just too cheap

Most studies conclude that it is hard to find a way to add free goods into GDP. We can probably add no more than 0.1% p.a. to GDP growth. The reason is simply that digital goods are just too cheap. Once created, apps can be reproduced at zero cost and vast amounts of data can be stored and manipulated at very low cost. The story would be different if we tried to measure welfare because then we would be asking about the value to consumers rather than just what it costs to produce.

The sharing economy and digital services

Another challenge for statisticians is to capture the 'sharing economy'

Another challenge for statisticians is to capture the 'sharing economy', specifically the rapid growth of services like car sharing, (e.g. Zipcar), accommodation (Airbnb) and odd job services (TaskRabbit). The revenues of these companies themselves is in principle captured in GDP but, as we saw for intangibles, some of the payments may be routed via low-tax countries. Meanwhile, the revenues of the Airbnb hosts or the odd job men may not be fully reported. This is not a new problem of course. To calculate GDP, statisticians have to rely on surveys of businesses and tax returns and there has long been a casual or 'black' economy not fully captured. But as the digital economy makes it easier for people to become self-employed or work for a platform (sometimes in

[4] A ground-breaking research paper on the gains in well-being from digital goods can be found in https://www.nber.org/papers/w24514

addition to another job or a pension) just a few hours a week, the sharing economy is likely to raise new challenges to traditional tax systems[5].

As it becomes easier for people to work for a few hours a week, the sharing economy raises new challenges to tax systems

Another aspect of the sharing economy is the way in which technology has expanded the market for second hand goods, via platforms such as eBay or Amazon Marketplace. To some degree, this may have substituted for purchases of new goods, and therefore detracted from output. But by facilitating exchanges that would not otherwise have taken place it will have boosted the income (and hence spending) power of sellers and the welfare of buyers who might not otherwise have been able to buy.

One study found platforms add to welfare more through increased product variety than through increased competition and lower prices

Broadly speaking, platform business models raise new sets of challenges for statisticians and economists alike. On the one hand, they lead to efficiency gains via increased competition, but on the other hand they also typically lead to increased product variety for the same fixed fee or price. Therefore, this should raise consumer surplus, which is the difference between what consumers are willing to pay for an item or service versus the market price they actually pay for it. As an example, a research team led by MIT professor Erik Brynjolfsson showed that increased consumer welfare by product variety is seven to ten times as large as the consumer welfare gain from increased competition and lower prices in the online bookstore market. More disruptive technologies such as cloud computing are likely to compound these issues.

[5] The UK Office for National Statistics did some work on how to measure the size of the sharing economy here.

The second challenge: inflation

In this section, we argue that a second source of underestimation of real GDP growth is that official statistics may be overstating inflation. Although the problem of devising the price deflators to convert nominal into real GDP is hardly new, digitisation presents new problems. The rapid pace of innovation on digital goods and services may not have been adequately captured, thereby underestimating just how rapidly their prices have been falling.

Dealing with changes in quality

Statisticians deal with quality changes using the matched model and hedonic-based measures

One of the biggest challenge posed by the digital economy is to capture the fast-changing quality improvement of digital goods and services. Products like bananas and electricity supply do not change much over time. But most manufactured goods and services do indeed change, with new models and new features.

The matched model

Statisticians mainly deal with quality improvement using the so-called 'matched model', where quality improvement is split out from pure price changes. So what happens when a product changes or is discontinued?

The matched model seeks to split out quality improvement from pure price changes

The first approach is to assume that the change in price between the old model and its replacement is entirely due to better quality. Sometimes this could overstate the quality change, but most studies have concluded that quality improvement is likely understated with this approach, as the improvement in quality is typically greater than the increase in price.

The second approach is to try to estimate the change in quality directly. One way is to ask producers if the good is essentially the same as the previous product. If not, the statisticians ask about the value of the extra features contained. This of course produces a cost-based estimate of the enhancement, but it says nothing about the value to the consumer. Sometimes the difference may not be an added feature but a redesign of the user interface, as an example.

Hedonic adjustment techniques

But statisticians use 'hedonic' techniques instead of the matched model for about one-third of the US price index

For about one-third of the goods and services in the US price index, statisticians use 'hedonic' techniques instead of the matched model. The hedonic approach analyses a product by its attributes or features and calculates their contribution to the overall price. Then, by looking at the improvements of those particular attributes in a new model, weighted by their contribution, it is possible to estimate the effective change in price.

Take computers for example. The statisticians assess a large number of computers on sale with different characteristics, e.g. one with a faster processor, another with a longer battery life, another with a bigger screen and use complicated regression techniques to work out the contribution of these characteristics to the price of the machine. When a new computer model replaces an older one, its characteristics can then be analysed to see how much it should cost, according to the model. This can then be compared with the actual price to deduce the price change. So, if a new computer has a set of features which suggest it should retail for $1000 but it is actually available for $950 they conclude that prices have fallen 5%.

Hedonic techniques may not adequately capture quality in fast-moving digital markets

In practice, a substantial amount of judgement goes into the calculation and there are serious doubts over whether hedonic techniques adequately capture quality in a fast-moving area like digital equipment and software. Moreover, the approach requires a great deal of data and analysis, which is why the statisticians do not use it for everything. The matched model is the approach used for most goods and services.

Quality of the internet and the UK telecoms example

In the digital arena, the pace of change makes measuring prices a challenge

When it comes to measuring prices in the digital arena, one of the challenges is the pace of change. The official deflators show prices falling, but critics argue they have been falling far faster than officially measured if properly adjusted for quality.

Official statistics greatly understate the growing *quality* of internet services

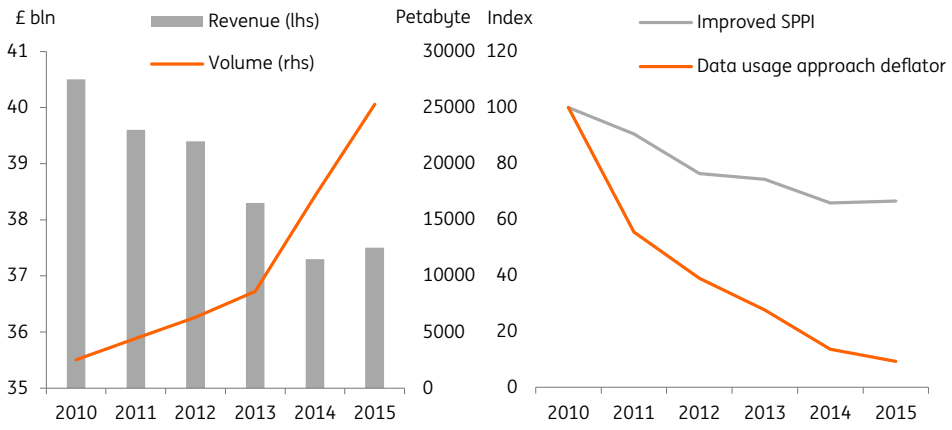
For example, the real value of internet services for consumers in the US national accounts is officially calculated to be up about nine times since 2000 to about 0.8% of GDP. Let's unpack that. About twice as many people are using the internet now as in 2000 and the average number of hours spent by each user has more than doubled in that time. So with the total number of hours on the internet up by over four times, that ninefold increase suggests that the *quality* of internet services has only about doubled since 2000. Given the massively improved speed, the hugely greater range of apps and content, the advent of video streaming, and the new ability to access the internet on the move, this seems highly implausible. Quality is surely up much more.

If the quality of internet services was up by 10 times instead of just doubling, GDP growth would be about 0.25% p.a. faster since 2000

How much difference might this make to GDP? On US data, if we said that the quality of internet services was up by 10 times instead of just doubling, GDP would be 4% higher or about 0.25% p.a. faster since 2000 (0.8% times five). Is that plausible? It is a matter of judgement of course, especially when we are talking about valuing services that are completely new, like viewing videos at the bus stop or checking messages on the train. But it seems defensible. Some might think it is still an under-estimate.

In another sign of the difficulties facing official statisticians the UK's ONS admitted in 2018 that it had got the telecoms deflator wrong for business telecoms **(Fig. 8)**. The problem was analysed in a paper published in 2017 by ONS statisticians and others, which focused on data usage in telecoms (Abdirahman 2017). This mis-measurement does not itself directly impact GDP because it relates to business telecoms which counts as an intermediate input. But it raises questions about the treatment of telecoms in the UK consumer sector, particularly in the 2010-15 period (see appendix).

Fig 7 Huge increase in data not mirrored by telecoms output



Source: ING, Office for National Statistics UK (ONS)

New digital products

Introducing new products into GDP has long been a problem. Usually, they are initially a very small amount of spending so are not counted. By the time they are counted, their price has often fallen significantly but this means that the real value of this good has increased particularly rapidly. So it could actually be adding more to GDP than is apparent from the small scale of spending.

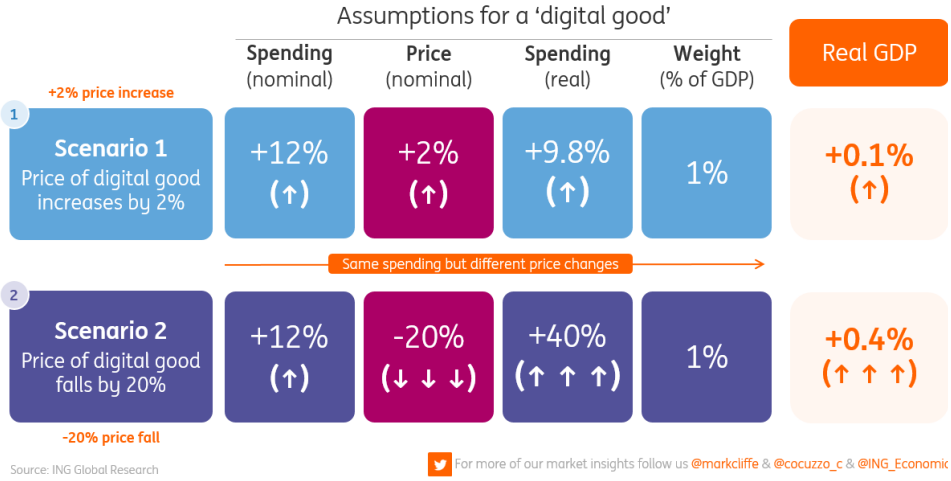
To see this, consider a new good on which spending is 1% of GDP. First, suppose spending on it rises 12% and its price is rising 2%, in line with the average of other prices in the economy. Then the real value of spending has risen 10% (approximately) and this

contributes to a 0.1% rise in real GDP. Now, again suppose that total spending has risen 12% but this time the price of the good has actually fallen by 20%. In this case, the value of real spending is up some 40% and real GDP is up by 0.4% **(Figure 9)**

The worry is that the digital era has brought many more new products and their prices may be falling particularly fast

This problem is not new: Video cassette recorders (VCRs) and mobile phones were added to price indices a decade after they were introduced. But the worry is that the digital era has brought more new products and their prices may be falling particularly fast. In practice, any individual new product will be added to official GDP long before spending reaches 1% of GDP these days. But if there are dozens of new products, each small but adding up to 1% of GDP and their prices are falling by 20% p.a., the effect is the same.

Fig 8 What happens to real GDP if the price of a digital good falls by 20%?



Source: ING Global Research

We do not include an estimate for the late inclusion of new products because it is impossible to calculate

In our overall assessment of the under-measurement of GDP we do not include an estimate for the late inclusion of new products because it is impossible to calculate across a range of different products. Official statisticians argue that the GDP statistics are actually quicker to incorporate new products than they used to be, although this is debatable. If we were to include a number it would be significant though still modest, for example 0.1% of GDP p.a.

Accounting for bundling

Smartphones do away with the need for several separate devices

For many people, smartphones do away with the need for a separate camera, music player, GPS device, map book, game player, calculator, torch and more. This is in addition to being able to make phone calls and send messages. But statisticians have a very hard time estimating the decline in prices when one product replaces several. The matched product model plainly doesn't work. Hedonic pricing could potentially do it by considering a smartphone alongside a basket of old goods, but it would be an extremely complicated calculation.

GDP misses the effective decline in prices when one product replaces several, which would be a boost to GDP

So GDP misses the effective decline in prices when one product replaces several, which would be a boost to GDP. But it does catch the fall in spending on those old products, as a decline in GDP. Computers were another product provided bundling in the past, offering word-processing, games, spreadsheets etc. But not too many old economy products (perhaps automatic washing machines being one example) involved much bundling.

E-commerce and the rise of the tech giants

Variety, timeliness and knowledge

Buyer search has become both cheaper and more efficient. None of this is captured in GDP yet it represents real progress

Before the internet people's consumer choices were limited to what they could find in nearby stores or through mail order companies. Harder to find items could require significant investment in time and effort to find them, telephoning perhaps or travelling a greater distance. What is the value of the immensely greater reach now provided by e-commerce? Almost anything available anywhere in the world is available through a quick search. Moreover, before buying, with a few clicks online consumers can compare not just prices but also quality with user reviews as well as professional reviews. In effect, buyer search has become both cheaper and more efficient. None of this is captured in GDP even though it represents real progress.

Amazonification of inflation: increased competition and lower costs

Rapid changes in retailing may bias inflation upwards. Producers can change prices rapidly in response to demand

There is little doubt that digitalization has made change faster. In a fast-changing retail environment, measured inflation may be biased upwards. Producers are able to change their prices rapidly in response to demand. Moreover, new producers are coming in all the time and are more accessible to consumers via the web.

A number of studies have confirmed that prices are being changed more frequently, increasing the volatility of inflation. However, the degree to which this has increased competition and reduced inflation is more controversial, with some suggesting that the inflation impact of e-commerce has so far been modest.

However, some argue that the inflation impact of e-commerce has so far been modest

Indeed, some, noting the market power of the tech giants and the rise of profit mark-ups, even suggest that e-commerce may have raised prices. However, while it is true that market concentration has risen, at least in the US, we are sceptical of this argument:

- The measured rise in mark-ups may have been distorted upwards because of the overstatement of inflation.
- Studies suggest that rises in mark-ups have been confined to a small number of internationally active 'super star' firms. Indeed, many traditional retailers have seen their margins squeezed.
- While e-commerce has been taking a rapidly rising share of sales, it is still far from dominant.
- Rising profits partly reflect the increased bargaining power of employers, which has enabled them to hold down wages.
- The digital ecosystems created by the Big Tech platform companies have increased competition not just in retailing but throughout the supply chain, increasing price transparency and market access for producers. Moreover, digital market places may have significantly reduced costs, for example in marketing or computing services, for producers, big and small.

Quantifying the effect of e-commerce on inflation is hard. Some say it is as little as 0.1%...

Quantifying the effect of e-commerce on inflation is hard. Some studies, which compare online and offline pricing, suggest that the negative effect is small: on the order of 0.1% in CPI terms. Moreover, the effect may be lower than it was few years ago.

...but others point to much bigger effects

However, other estimates point to much larger effects. A study by Goolsbee and Klenow, based on the Digital Price Index compiled from internet data scraped by Adobe Systems, found a 2.5% gap between similar items on and offline (Goolsbee 2018). Moreover, the narrowness of the gap between on and offline prices may simply reflect the degree to which competition is forcing traditional retailers to lower their prices.

Outlet substitution bias

Statisticians under estimate the impact of consumers saving by switching outlets

Another potential source of bias in calculating GDP is the so called 'outlet substitution bias'. If a new store offers goods more cheaply consumers will switch to it. But when the statisticians use their matched models they have a fixed sample of stores they check for prices so they will only add the new outlet at some point after consumers switch to it. And then it can only be included in the deflator the second month it is sampled (to get the matched change) which means the initial price fall enjoyed by consumers – the reason for their switch - is not captured. Moreover, new producers are coming in all the time and are more accessible to consumers via the web.

That said, this problem is likely damped to some extent by robust competition: existing retailers will need to reduce their prices to compete, which will be captured in the official matched model data. This could mean that outlet substitution bias in the digital era is less of a problem than it used to be.

"Uber has radically reduced the price of on-demand taxi services in many cities. And Airbnb has radically reduced the price of accommodation. These effects may not have been captured."

However, some of the new digital services have had a dramatic effect on prices. For example, Uber has radically reduced the price of on-demand taxi services in many cities. And Airbnb has radically reduced the price of accommodation. These effects may not have been captured.

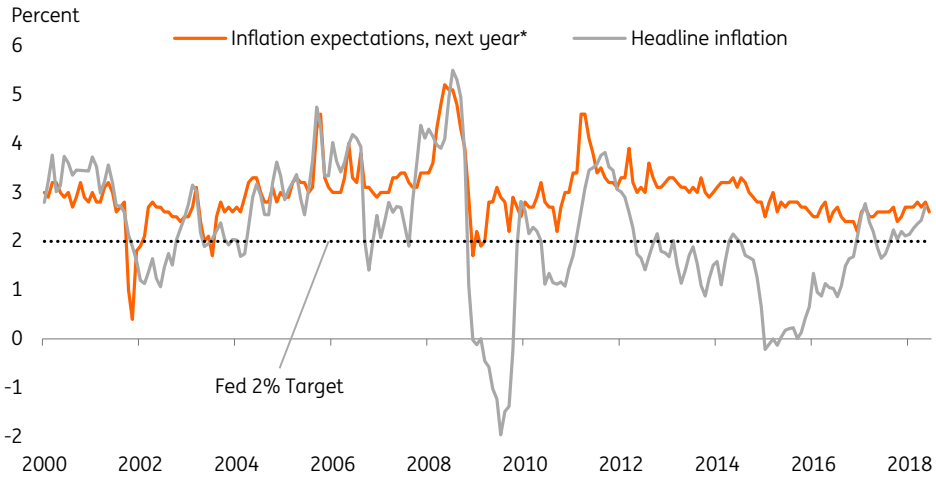
Is much lower inflation plausible?

Martin Feldstein argued that the over-estimation of inflation for GDP as a whole could be 1 or even 2% p.a.

The late Martin Feldstein argued that the over-estimation of inflation for GDP as a whole could be 1 or even 2% p.a. (Feldstein 2017). He argued that inflation has long been overstated, even before the digital era, because of problems in making quality adjustments and allowing for new products especially in services. But for some people, these claims raise credibility issues.

First, most ordinary consumers reckon inflation is higher than official estimates, not lower. For example, the University of Michigan survey of inflation expectations has averaged around 3% p.a. since 2000, yet the Federal Reserve has been concerned that inflation has been below its target of 2%. **(Fig. 10)**

Fig 9 Ordinary consumers think inflation is higher than official estimates show



* based on a survey based measure by the University of Michigan
** measured as the year-on-year change of the Consumer Price Index, all urban consumers, all items
Source: ING, Macrobond

> *"Consumers tend to notice the price of products they buy frequently like food, coffee and petrol and pay less attention to infrequent purchases of large items such as cars, washing machines or computers"*

One reason for this over-estimation is that consumers tend to notice the price of products they buy frequently like food, coffee and petrol and pay less attention to infrequent purchases of large items such as cars, washing machines or computers. Yet the lowest inflation, or often deflation, is in the prices of those long-lived manufactured goods and they make up a large part of consumer spending.

When thinking of the cost of living, people tend to overlook the rising quality of new models

Another reason is that people tend to think in terms of their 'cost of living'. When they need a new car, TV, washing machine or computer their perceived rate of inflation is what is happening to the prices of those goods *as offered*. The fact that the new models have more features or are of higher quality than the last time purchased is not part of peoples' thinking **(Fig. 11).**

Fig 10 Higher Energy and Food inflation in the US helps to explain different consumers' perceptions (%)

	Weighted Energy & Food	Headline inflation	Core inflation
since 1990	3.01	2.47	2.42
since 2000	3.26	2.19	1.99
since 2010	1.94	1.75	1.79

Source: ING, Macrobond

But if we extrapolate backwards a much greater price fall, it implies that people in the past were implausibly poor

The second issue is sometimes called the Hulten Paradox (Reinsdorf 2017). The point is that if we extrapolate backwards a much greater price fall than claimed by the official statistics, it could imply that people were implausibly poor in the past. Ultimately, judging whether deflators are correct is a subjective exercise. We will come back to this point below.

Push-back from official statisticians

Two groups of senior US government statisticians have pushed back on claims that GDP is grossly under-measured, arguing that technology enthusiasts are exaggerating the extent of the distortions. One study looks closely at three effects: under-adjustment for quality change, under-adjustment for replacement of non-digital goods with digital goods (e.g. streaming services replacing CDs) and improved variety selection such as clothing and books via on-line stores (Reinsdorf 2017).

The study dives deep into individual products and looks at how they are affected by the digital revolution. It reckons that about 3% of consumer spending is on products directly affected by rapid quality improvement such as computers, software and telephone equipment, and a further 7% is on products potentially affected, because they have digital components, including cars and household appliances. A further 20% of products and services may be affected by digital replacement or subject to increased variety. This leaves almost 70% of products and services, like basic food, utilities and housing, which, they argue, are unlikely to be affected by the digital revolution.

Two groups of US government statisticians argue that technology enthusiasts are exaggerating the distortions

Then they apply a 5% p.a. lower price deflator for the 3% directly affected products and a 2% p.a. lower price deflator for the 7% of potentially affected products. This has the effect of lowering the consumption deflator overall by about 0.3% p.a. To this, they add their estimate for the effect of digital replacement (0.1-0.2%) and increased variety (0.06%). They conclude that the consumption deflator could be at most about 0.5% p.a. over-estimated, though they argue this is an upper bound. Consumption is about 70% of GDP so this would directly translate to about 0.3% p.a. faster GDP growth. However, they do not attempt to calculate the effect of truly novel products, like the smartphone. They point out that GDP has always missed the initial introduction of new products and never been able to truly assess their new value. For example, GDP never included the value of

replacing the horse with the car or the dish mop with the dishwasher. What matters is how quickly new products are included in GDP and they believe new products are included faster than in the past. Nor do they include free products, which they argue are simply beyond the scope of GDP. Another study by official statisticians, sub-titled 'A View from the Trenches' also looked at the issue of quality and new goods (Groshen 2017). They arrived at a figure of 0.4% for the under-estimation of GDP, this time including investment. Their analysis found that problems on the consumption side accounted for a 0.26% under-estimation in 2015 and on the investment side, 0.15%.

Assessing the official view

These two official estimates are quite close, at about 0.4% of GDP if we add the figure for the investment deflator from Groshen (0.15%) to the Reinsdorf estimate which is only for the consumption deflator. How to assess them?

Adding the 0.1% for free goods to estimates by official statisticians suggests GDP may be understated by 0.5%...

First, it is likely they are still not appreciating the true extent of the quality improvement and implied price decline. For example, in the Reinsdorf study the 5% lower price profile for directly-affected products is low compared to the UK's problem with telecoms, which would imply a minimum of 6% p.a. over-statement of prices (35% over five years) and potentially much more. And our appraisal of the gain in the quality of internet services since 2000 is much higher than the official US figures. So although these studies both claim that their numbers provide an upper bound to mis-measurement they may still be too conservative. Secondly, while both studies make a good case that there are practical difficulties with including free goods, the fact is that the digital revolution has produced a plethora of new free goods. Arguably we should at least add the estimate above of 0.1% p.a. based on 'viewership services'. Thirdly, they don't address the question of investment in intangibles which we have found could add a further 0.2-0.3% to GDP.

...and if we add a further 0.25% for intangibles we have a figure of 0.75%

The bottom line: how much under-measurement?

However, this figure still excludes several items where we have no estimate available

If we use the 0.4% estimate by official statisticians for how much GDP may be understated and add the 0.1% for free goods, we have a figure of 0.5%. If we add a further 0.25% for intangibles, we have a figure of 0.75%. However, this figure still excludes several items discussed above where we have no estimate available at present. These include the late inclusion of novel digital products (where the big price fall occurs before they are included), the price decline when a product bundles several products that were previously bought separately, the effects of outlet substitution bias and, more broadly, the mis-measurement of quality improvements in non-digital services. Given these exclusions, we would argue that the 0.75% may still be an under-estimate and we would put the upper bound for a reasonable range at 1% or potentially even higher.

Fig 11 Calibrating the mis-measurement: the GDP Digital Remix

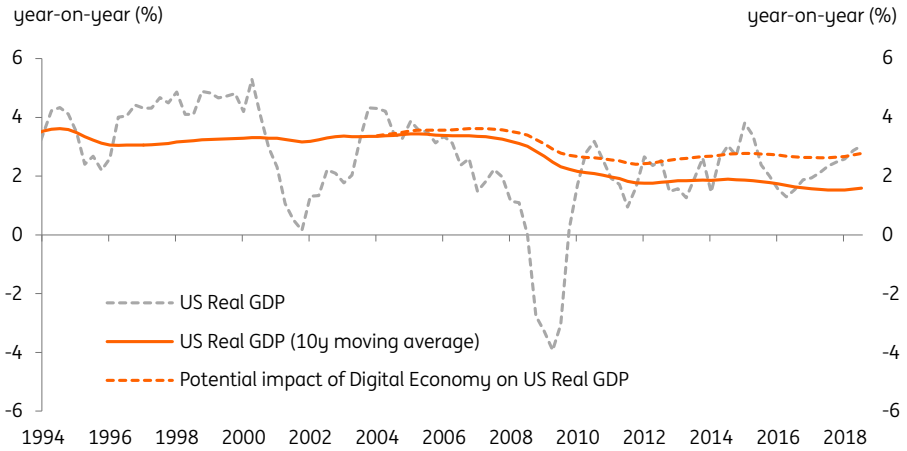
% p.a.	Nominal GDP	Inflation*	Real GDP
What's left out			
Intangibles	↑↑ 0.25	≈ no est.	↑↑ 0.25
Free goods	↑ 0.1	≈ no est.	↑ 0.1
Sharing economy	≈ no est.	≈ no est.	≈ no est.
Mis-measurement of the deflator			
Quality change in digital products	≈ no est.	↓↓ -0.2	↑↑ 0.2
Digital products replacing non-digital ones	≈ no est.	↓ -0.1	↑ 0.1
Improved variety due to digital platforms	≈ no est.	↓ -0.1	↑ 0.1
Late inclusion of novel digital products	≈ no est.	↓ no est.	↑ no est.
Bundling in digital products	≈ no est.	↓ no est.	↑ no est.
Outlet substitution bias	≈ no est.	↓ no est.	↑ no est.
Quality improvements non-digital services	≈ no est.	↓ no est.	↑ no est.
TOTAL**	↑↑ **0.35**	↓↓ **-0.4**	↑↑↑ **0.75**

Data: percent, year-on-year.
*GDP deflator. Consumer prices may differ slightly.
** of items where estimates are available.

We could add another 0.5% p.a. from other mis-measurements, particularly in services. So GDP may have been understated by 1-2% p.a. for decades

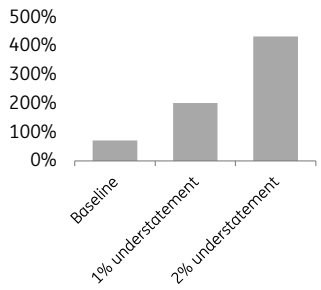
All of this relates only to mis-measurement of the digital sector and intangibles. We could probably add a further 0.5% p.a. from other mis-measurements, particularly the broad failure to capture services effectively. So GDP could have been understated by 1-2% p.a. for decades, with the trend worsening with the rise in services and intangibles and even more so with the expansion of the digital economy **(Fig. 13)**

Fig 12 US real GDP could be understated by over ¾% p.a.



Source: ING estimates; Macrobond

Real median income change 1959-2016



Source: Reinsdorf, Schreyer (2017)

A 1% p.a. mis-measurement alone would suggest that people are 50% better off than in 1990, rather than only 15%

Are these estimates plausible?

The first question to ask is whether these estimates seem plausible, going back to the Hulten Paradox mentioned earlier. According to the official figures, median US household income rose only 15% from 1990-2017. (Average incomes rose far more, over 50%, but the worsening distribution held back the median). **If the statisticians have got the price deflator wrong by 1% p.a. then real household median income would be up 50%, while a 2% mis-measurement would mean a 96% rise, or almost double**. (Note this assumes that the distribution of the extra GDP is proportional to 1990 incomes and is not weighted towards higher earners. This seems likely given that new digital technologies are cheap and widely held).

To recap what this is saying**:** If we allow for the improvement in quality of just about all goods and services since 1990, as well as the benefits of new goods (the internet, Wi-Fi, smartphones, search, Facebook and all the rest in the digital sector as well as improvements in other areas) then people are somewhere between 50% and 96% better off than 28 years ago. How can this be true? It could be some combination of the following, though note that the categories overlap somewhat since new products often replace old products:

- Goods and services where the average person enjoys more quantity, perhaps meals out or holidays abroad. If we focus on the digital area we can cite photography, phone calls, information retrieval, touchpoints with friends, videos.
- Goods and services where the change is primarily one of quality. In the old economy how much better is your car than the one you or your parents drove in 1990? One way to think of it is to compare a luxury car in 1990 costing twice as much as an average family car then, with an average car now. On metrics like acceleration times, top speeds, extras such as air conditioning, multiple airbags or heated seats, there probably isn't much difference. Are meals out of higher quality today than 28 years ago? It is a matter of opinion but here are some reasons why we might say yes: better education of restaurant workers; better machines for keeping food hot; better wine; easier booking services; increased competitive pressures from user reviews. In

the digital area we can point to information retrieval, video games, photography, education etc.

- New products which radically improve lives. The biggest change is in the digital area, notably smartphones, social media, streaming and video phoning. But there are new products in many other areas too. For example, in medicine we have stents, portable defibrillators, anti-retroviral treatments for AIDs, robot surgery and DNA testing.
- Increased choice. This may have occurred in the old economy due to globalisation adding new product ranges from manufacturers in other countries but it has plainly been accelerated by the internet and internet shopping which gives access to a far greater range of choice than before.

But against these we have to set areas of spending and life where things have not improved very much if at all. For example, is the average house much different from 28 years ago? Some may have better insulation, improved heating and cooling, better floor and window coverings or smarter kitchens. But it is doubtful that many are nearly twice as good as before, and some will not have changed at all. Indeed, certain goods and services like electricity supply or many foods may have remained the same.

We have not addressed the impact of non-market activities which harm the sustainability of GDP

Meanwhile, some people will argue that certain things have become worse. More broadly, the impact of non-market activities which harm the sustainability of GDP are beyond the scope of this report and are surely worthy of their own remixes.

The Hulten Paradox again

What if we extend the mis-measurement further back? This is where some analysts become uncomfortable

What if we extend the mis-measurement further back than 1990? This is where some analysts become uncomfortable. For example, if we go back to 1959, we find that the data shows US real median household income up about 70% using the official figure for the consumer expenditure deflator of 3.3% p.a. on average (Figure 14). But if we assume that inflation has been over-estimated by 1 percentage point p.a., so that inflation really only averaged 2.3% p.a. then the real median income is up about three times (from $19,588 to $59,039 in 2016 dollars). Which is more plausible, a little less than doubling, or tripling? It's not evident that a threefold increase is too much. However, if we assume that inflation has been overstated by 2ppt, then real incomes are up fivefold. That does sound too much.

Official data from 1959 show US real median household income up about 70%, based on the consumer expenditure deflator of 3.3% p.a.

Fig 13 US Median income per household under alternative inflation assumptions

Year	Price basis	USD
2016	2016	59,039
1959	1959	5,400
1959	2016 with official PCE deflator	34,636
1959	2016 prices with assumed 1% PCE overstatement	19,588
1960	2016 prices with assumed 2% overstatement	11,077

Source: Reinsdorf, Schreyer (2017)

But if inflation has been over-estimated by 1% p.a., then the real median income is up threefold

In our view, the answer to the Hulten Paradox is that GDP has been mis-measured at an accelerating rate as services and more recently digital products have become a larger share of GDP. So back in the 1950s, 60s and 70s the mis-measurement was probably small. Much of the gain in incomes was coming from more people owning cars, TVs, washing machines, air-conditioning etc., all goods which could be relatively easily measured. But as American households began to become satiated with standard material goods, growth switched more to improved quality of those goods as well as services. From the 1980s on, the digital revolution took off leading to an increasing rate of mis-measurement.

Can digital technology mis-measurement explain the post-2004 slowdown?

Studies suggest that US productivity has slowed significantly since the early 2000s with a marked break in 2004 (Fernald 2014). Trend growth in GDP and productivity seem to have slowed by about 1.1% p.a. since 2004 compared with the 1995-2004 period (see fig. 2 on page 4). The fact that the break happened before the financial crisis has led many people to search for a cause linked to technology rather than simply to blame recent poor figures on the aftermath of the crisis.

Another mis-measurement is that official data for business investment shows a decline

But if the digital economy is not being measured correctly, have GDP and productivity growth in fact slowed at all? We will be returning to this issue in more depth in a later paper but a few preliminary points can be made here.

- We have just argued that mis-measurement of GDP arising from digital developments likely amounts to at least 0.5% p.a. with mis-measurement of intangibles adding a further 0.25%. But some of the mis-measurement will have started before 2004. Google and Wi-Fi were introduced before then and the personal computer long before. The increased role of intangibles also began a long time ago.

When intangibles are fully included, business investment is no lower than before

- Nevertheless, the spread of the digital revolution to more people in the last decade, with mass adoption of the smartphone, the emergence of a myriad of new apps and massive expansion of content does support the idea that digital mis-measurement has become greater.
- Still, it is hard to match that to a hard break in 2004.

It would seem then that it is difficult to account for the whole slowdown with mis-measurement *starting* in 2004. But as much as half could be accounted for that way. We will return to this question in a later paper.

This throws doubt on one explanation for the GDP and productivity growth slowdown

One of the other mis-measurements in the national accounts is that official data for business investment shows a decline. As we have seen, when intangibles are fully included, business investment is no lower than before. This throws doubt on one of the main explanations that has been offered for the slowdown in productivity and GDP growth. There are other explanations centered on the effects of the global financial crisis, for example the survival of zombie companies with the help of ultra-low interest rates, or regulatory barriers. But many experts on technology argue that there has been a lull in the *application* of the new technologies and that this did indeed start around 2004.

A lull in digital applications?

According to this story there was a surge in the use of digital technology in business in the late 1990s and early 2000s when the personal computer and internet were united. This created great efficiency savings. Wholesale and retail trade made particular use of the new connected technologies, implementing ordering and inventory control systems which brought major savings.

One story is that the efficiency gains from this wave of advance petered out in the early 2000s

More broadly, these systems encouraged the expansion of supply chains within and across countries again leading to efficiency gains. Another big area of gains was in office administration where the new systems allowed centralised buying, and self-management of information systems. It also made outsourcing of functions possible for both large and small companies.

Continuing with the story, the efficiency gains from this wave of advance petered out in the early 2000s and have not been replaced by newer technologies. The efficiency gains from mobile computers (tablets and smartphones) have not yet, it seems, had the same

We believe that any lull in digital applications is likely to be temporary

impact. Moreover – and this is an important part of the story - the transformation of the consumer experience with the explosive growth of social media, e-commerce and the like may have increased welfare substantially but has less impact on GDP. The so-called consumer surplus – the gap between what you pay and the value you receive – is likely higher than ever in the digital era because digital stuff is so cheap. We are planning to tackle this issue in a subsequent report.

New digital technologies offer the potential for radical and rapid transformation, which justifies labelling them as new 'general purpose technologies'

In any case, we believe that to the extent there has been a lull in digital applications, it is likely to be temporary. More cautious voices about the pace of the coming upturn cite the example of electricity. Electricity was first used in electric lighting in the late 19th century and usable electric motors became available around the beginning of the 20th century. But factories only gradually switched over from steam power to electric power over 30 years or more and, initially, the productivity gains were minimal. It takes times to reorganize processes.

Outright technology optimists counter that compared to previous waves of technological change, the pace of adoption of the new digital technologies has been much faster. Moreover, the near zero marginal costs of new digital technologies such as the cloud, AI, big data, IOT point to the potential for exponential growth.

But adoption may be constrained not just by the investment and restructuring needed, but also by the social and political resistance

In our view, the truth will likely fall somewhere in between. The new digital technologies offer the potential for radical and rapid transformation, which justifies labelling them as new 'general purpose technologies'. However, the pace of adoption may be constrained not just by the scale of investment and organisational restructuring required, but also by the social and political resistance that they entail.

Conclusion: the implications of under-measurement

The digital era has intensified the problems of measuring Gross Domestic Product

The digital era has intensified the problems of measuring Gross Domestic Product. This most quoted of economic statistics has always been flawed and error-strewn, and yet these problems have been widely overlooked. In this report we have started to address them, attempting to quantify at least some in our GDP Digital Remix. We have done so knowing full well that the numbers are easily contestable. Moreover, we intend to revisit the shortcomings of GDP as a measure of welfare or future prosperity.

But new digital technologies clearly offer the potential for radical transformation, which justifies labelling them as new 'general purpose technologies'

Nevertheless, we feel comfortable with our preliminary conclusions about the impact of digitalisation on output and inflation. The new digital technologies clearly offer the potential for radical and rapid transformation, which justifies labelling them as new 'general purpose technologies'. The near zero marginal costs of new digital technologies such as the cloud, AI, big data, IOT point to the potential for exponential growth**.** That said, some techno-optimists have taken the argument too far. The pace of adoption may be constrained not just by the scale of investment and organisational restructuring required, but also by the social and political resistance that they entail.

- **The digital era has exposed, more than ever, the limits of GDP as a measure of welfare.** Because of the zero or very low cost of reproduction of software and data, the consumer surplus on digital services is much larger than for most other goods and services. We will look at this further in a later report.
- **Living standards are not stagnant as widely assumed but are still rising**. If GDP has been under-estimated by 1% p.a. since 1990, then median income has risen 50% instead of the 15% recorded. And if we just take the period since 2007, median incomes are officially reported up just 5.5%. With 1% p.a. under-measurement the right figure would be 16.5%.
- **Inflation is lower than recorded.** To the extent that the problem has been worse in the last decade it would help explain why inflation did not fall further after the GFC. When unemployment rose sharply in 2009 and the recovery was only slow, economists were baffled that inflation had not fallen further as models suggested.
- **Some of the mis-measurement discussed has the effect of raising recorded investment as a percent of GDP.** As already noted, if correct, this supports the idea that GDP has not slowed as much as believed. It should also support continued GDP growth in the future.

We will explore the economic, financial market and policy implications in more detail in a future report. Clearly, since our Digital Remix calculations suggest conservatively that Real GDP growth has been underestimated by 0.75% p.a. and inflation overestimated by 0.4%, these implications are profound. But we would caution that other distortions to GDP are less benign: the only safe conclusion is that economists should be far more humble about the reliability of their favourite economic statistics.

Appendix

Summary of studies and main findings

Study	Area	Effect on measures
Nakamura et all 2017	Better accounting for free goods by treating households as producers of 'viewership services' that they barter for consumer entertainment	Adds 0.11% pa to US GDP from 2005-15
Feldstein 2017	General survey of a range of issues	He "can imagine" GDP growth is 1-2% higher than measured
Samuels and Soloveichik 2017	Valuing free content	Adds about 0.1% to GDP growth
Ahmad et al (2017)	Adding free media funded by advertising to household consumption Adding Wikipedia to US GDP	Would increase GDP growth by 0.07% in 2011-13. On extreme assumptions could add 0.1% to global GDP level.
Byrne and Corrado 2017	Include digital capital services in consumption and GDP	Adds about 0.2% to GDP growth
Corrado, Hulten, Sichel 2006	Add all intangibles to GDP	Adds about 10% to GDP level. If we spread it over 30 past years, 0.3% pa to growth
Byrne and Corrado 2017	ICT sector itself. Deflator is falling much faster than measured	Adds 0.22% pa 2004-14
Reinsdorf and Schreyer (official statisticians) 2017	Upper bound adjustment to consumption deflator for quality change (-0.3%), digital products replacing non-digital (-0.1-0.2%) and variety gains (-0.06%)	Total about -0.5% to consumption deflator. Would add 0.3% pa to GDP
Groschen et al 2017 (US government statisticians)	Issues with consumption and investment deflator	Adds about 0.4% to GDP
Abdirahman, Coyle et al 2017	Assess telecoms output, which has officially declined. Find the deflator is severely biased upwards and should actually show a 35-90% decline	Does not change GDP directly because applies to business. But it is suggestive that telecoms for consumers may have been miscalculated too

Source: ING

Bundling – take a photo

Photography is an interesting case of bundling. Creating a photo used to require owning a stand-alone camera and then buying film and paying to have it developed. Each photo costs about 30 cents per view in today's money, plus the cost of the camera. Most people kept cameras for many years so the extra cost per view was probably another 5-10 cents or so. Today with your smartphone you can snap a photo and share it instantly with friends and family. Yet the net result in official GDP is a decline, as the cost of stand-alone cameras, film and developing drop out.

Moreover the improvement in picture quality in recent years may not be adequately captured. Statisticians do try to take account of improvements in quality in smartphones for example. But it is doubtful if they capture it fully. Consider the massive improvements in the in-phone cameras since the early ones and then multiply by the number of pictures taken, for example. And then add videos and selfies too, as well as the ability to edit images easily.

How might we measure the change? Consider a typical amateur photographer who, 20 years ago, might have snapped 10 rolls of film a year, mostly on holidays or days out. (Digital cameras first appeared in the early 1990s but were not widespread until the early 2000s.) Films usually provided 36 exposures so 360 snaps in all. In today's money it would probably cost about $130 to do that (and yes it can still be done!) Now, the camera in your phone doesn't actually cost nothing. It costs money to include in the device and there is evidence we are willing to pay more for a phone with a better camera: An improved camera is often one of the key selling points of new models.

Let's suppose that you are really paying about $200 for the camera when you buy a new phone: perhaps you could have bought a cheaper one with a poor camera for $200 less. This may be on the high side but if the typical phone is kept three years, that works out to just $67 a year. (If it is a high estimate the point would be stronger.) I have deliberately arranged this number to be about half the cost of photography 20 years ago. So, at first blush the cost of photography has been halved.

But now the question is how many photos do you take? If you take exactly 360 then the cost of your photography has indeed halved which is equivalent to productivity doubling. If we spread that out over 20 years we could say that the productivity of photography has grown about 3.5% p.a.. But many people take far more than 360 photos a year and shoot videos as well. The number of photos taken globally is estimated to have risen from 80 billion in 2000 to 1.6 trillion in 2015 and is likely more than double that level already in 2019, given the spread of the smartphone. So it seems productivity in this area has much more than doubled. But because bundling is not captured by the statisticians none of this is captured in GDP.

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