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The macroeconomic implications of measurement problems due to digitalisation

Juha Itkonen

Abstract

The impact of digitalisation is not fully reflected in economic statistics. Even though commonly used economic metrics such as GDP are still relevant in assessing the state of the economy, the production of statistics should be developed to measure the digital economy better. The most significant measurement challenges caused by digitalisation relate to new goods, free services, changes in quality and the movement of intellectual capital between countries. Due to digitalisation, GDP and productivity growth may have been understated and the rate of price inflation overstated. Measurement errors alone do not explain the exceptionally weak development in recent years, nor do they eliminate the problems of the Finnish economy and the key challenges for economic policy. Digital technology has, however, improved our well-being in ways that are difficult to measure in money.

Keywords: GDP, digitalisation, statistics, productivity, technology

JEL codes: E01, E31, D63, D23, O33

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1 Introduction

Digitalisation is understood as the widespread introduction of information and communication technology (ICT) in the various sectors of the economy. Digitalisation is reshaping production methods and structures and creating new products and services, and it is expected to be a significant driver of productivity and economic growth in the coming years (Brynjolfsson and McAfee 2014, Pohjola 2014).

Although new digital technology is already reflected in many ways in the day-to-day lives of individuals and businesses, in the national accounts its effects have been smaller than expected. The conflict between everyday experience and statistics has raised the question of the extent to which economic statistics are able to describe the transformation brought by digitalisation and whether new metrics are needed alongside the traditional ones.

Furthermore, measurement errors have been proposed as an explanation of the many exceptional economic phenomena that have affected the developed economies in recent years. Slow economic growth, slow productivity growth, low inflation, low investment and low real rates of interest could be, in part, explained by the measurement problems exacerbated by digitalization.

In this paper we assess the impact of digitalisation on the accuracy and reliability of key statistics related to prices and to the size, structure, and growth rate of the economy. We survey measurement problems and aim to form an overview of the challenges of measuring the economy in the digital era.

We show that the significance of digital goods for the economy and social well-being is difficult to measure for several reasons. Digitalisation brings about new goods, changes the quality of existing goods, and often provides free services which makes measurement problematic. Luckily, similar measurement challenges have emerged in the past, so conceptual tools to tackle new problems already exist (Ahmad and Schreyer 2016).

We find that overall the current statistical framework and concepts are sufficient for most economy policy purposes and a bulk of economic output can be measured appropriately, but measurement practices need regular updates as digitalisation unfolds. Even though it is difficult to quantify measurement errors exactly, it is likely that GDP growth has been slightly faster than measured.

National statistical authorities and international organisations, such as the OECD and the IMF, have recently begun to review the appropriateness and reliability of economic metrics in the digital economy. In 2016, the Bank of Finland and Statistics Finland set up a joint working group to analyse the measurement challenges brought by digitalisation. This article presents the results of the working group's analysis from a macroeconomic perspective.[1]

The paper is structured as follows. Section 2 examines how digitalisation is reflected in economic statistics. Section 3 surveys key metrics of the national economy and their potential

[1]Taking digitalisation into account in the national accounts and price indices is covered in more detail in articles by Tuomaala and Koskiniemi (2017) and Hellman (2017).

measurement errors. It also considers their capacity to explain the exceptional economic phenomena of recent times. Finally, conclusions are presented for users of statistics and decision-makers.

2 Is digital structural change reflected in statistics?

Digital devices and services have been widely introduced in various population groups and have become intimately integrated into people's everyday lives. Digitalisation is reflected in many statistics describing consumer behaviour, but in the national accounts, which describe the economy as a whole, the phenomenon is less visible. The accounts' relatively rough classifications of goods and economic activities are ill-suited to assessing the structural change brought by digitalisation. For this reason, the phenomenon should be described using a broader set of metrics (OECD 2014).

2.1 Statistics describing consumption

Digital devices and internet connections have rapidly become commonplace in households during the past two decades (Figure 1). In recent years, mobile devices and connections in particular have spread widely and quickly. The importance of mobile technology is also evident in the strong growth in the amount of data transmitted on mobile communication networks, which has been roughly doubling annually (Figure 2).

Finns' now use the internet on an everyday basis. Nearly all of the young age groups use the internet daily and the proportion of everyday users has also grown rapidly in older age groups (Figure 3). Internet use in work and at home have become commonplace in all age groups and socio-economic classes.

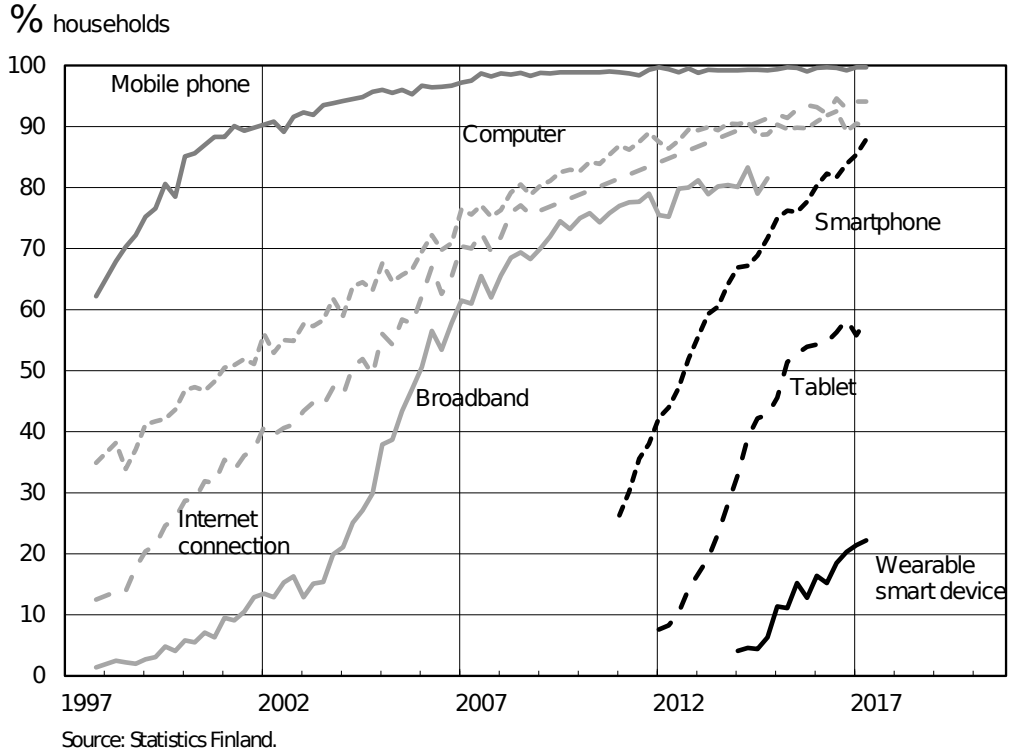
In some markets, the change in consumer habits has been particularly strong. In recordings, for example, the proportion of digital sales and particularly of music subscription services has grown rapidly (Figure 4). In 2016, already 75% of recording sales were digital.

In consumer prices, digitalisation was been reflected in a rapid fall in the prices of ICT equipment and services. During the past twenty years, real prices have been halved in communications services and have fallen to less than one-tenth in data processing devices (Figure 5).

2.2 ICT goods and ICT production in the national accounts

An attempt can be made to describe digitalisation with the aid of the national accounts by examining the goods or economic activities that are most relevant to information and communication technology. In practice, however, goods and economic activity classifications are ill-suited to examining the phenomenon, because ICT would appear be an intrinsic part of activities throughout the economy. The phenomenon can be compared to electricity and the

Figure 1: Prevalence of devices and connections in households

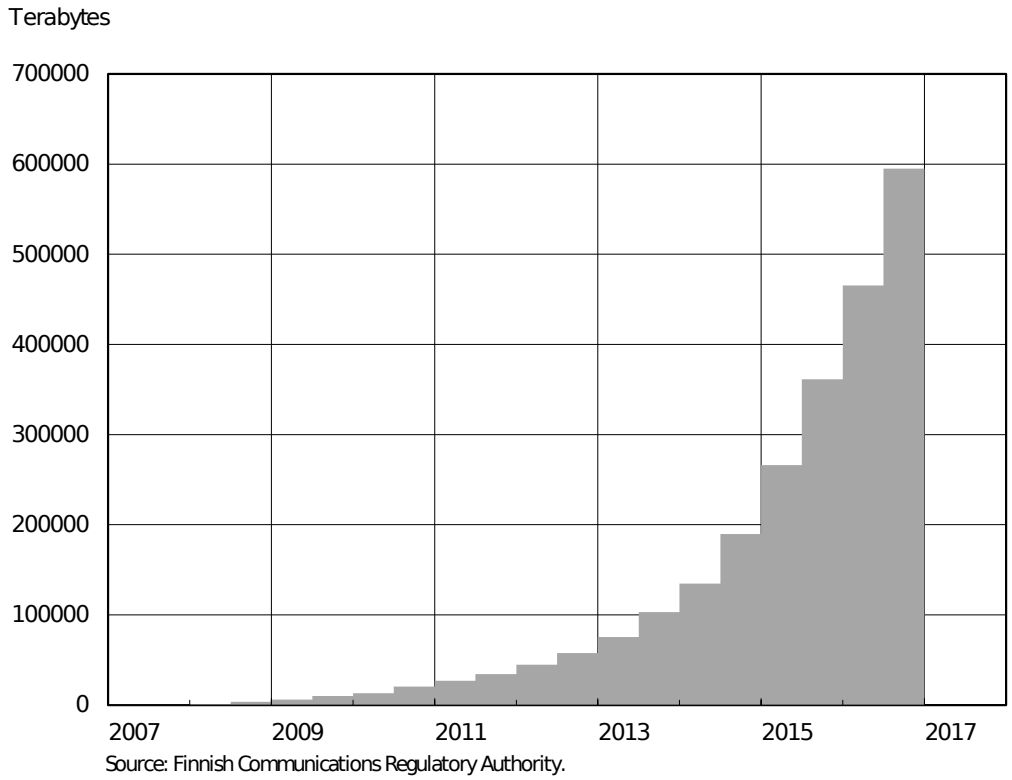


impact of its introduction in the 20th century. General-purpose technologies boost the economy so widely that it is not always possible to distinguish which part of economic development is due to digitalisation. For example, banking and travel reservation services, where the significance of ICT is currently high, are recorded in the economic activity classification of the accounts under banking and travel services. In the national accounts, the consumption volume of actual ICT goods such as data processing devices and telecommunication connections has grown very rapidly (Figure 6). Over the past 20 years, the consumption of ICT goods has grown at an average annual rate of over 10%.

ICT goods' expenditure share of household consumption has remained modest, however, and has even declined in recent years (Figure 7). In 2015, household consumption expenditure on ICT equipment and services was only 2.6% of actual individual consumption (1.9% of GDP). Falling prices have kept the expenditure share of digital goods small, and therefore the impact of this group of goods on overall growth in consumption is small.

A similar phenomenon is also seen when the production of ICT industry and services is examined (Figure 8). The value-added price of the electronics industry and telecommunications has fallen rapidly, which has reduced the weighting of these economic activities in GDP. An exception is data processing services, where both price and volume have increased. Due to the small weighting, the ICT sectors' contribution to total economic growth appears small when it is compared with the volume growth of these sectors. In Finland, however, the growth rate and weighting of the ICT sectors have been so high that they account for a significant part

Figure 2: Data transferred on mobile communication networks



of the economic growth of recent decades (Pohjola 2017).

3 Key metrics and measurement problems

The purpose of measurement is to attach to a property of a measurement object a quantity that enables comparison. When assessing economic metrics, it is important to consider the kind of comparison for which they have been designed. No single metric can answer exhaustively all questions in all circumstances; several are typically needed to capture the different aspects of the phenomenon observed.

In assessing the measurement challenges created by digitalisation, it is therefore necessary to distinguish problems associated with a metric's appropriateness from problems associated with its accuracy. An appropriate metric is suitable for a specified purpose and yields answers to the questions presented. An accurate metric, in turn, captures precisely and unbiasedly the phenomenon it is intended to measure according to its definition.

To a large extent, the new measurement problems are comparable to problems already known, which have also been covered extensively in the research literature before the age of digitalisation. There follows an examination of the impact of the measurement problems created by digitalisation on the assessment of the size and structure of the economy, price

Figure 3: Daily use of the internet by age group

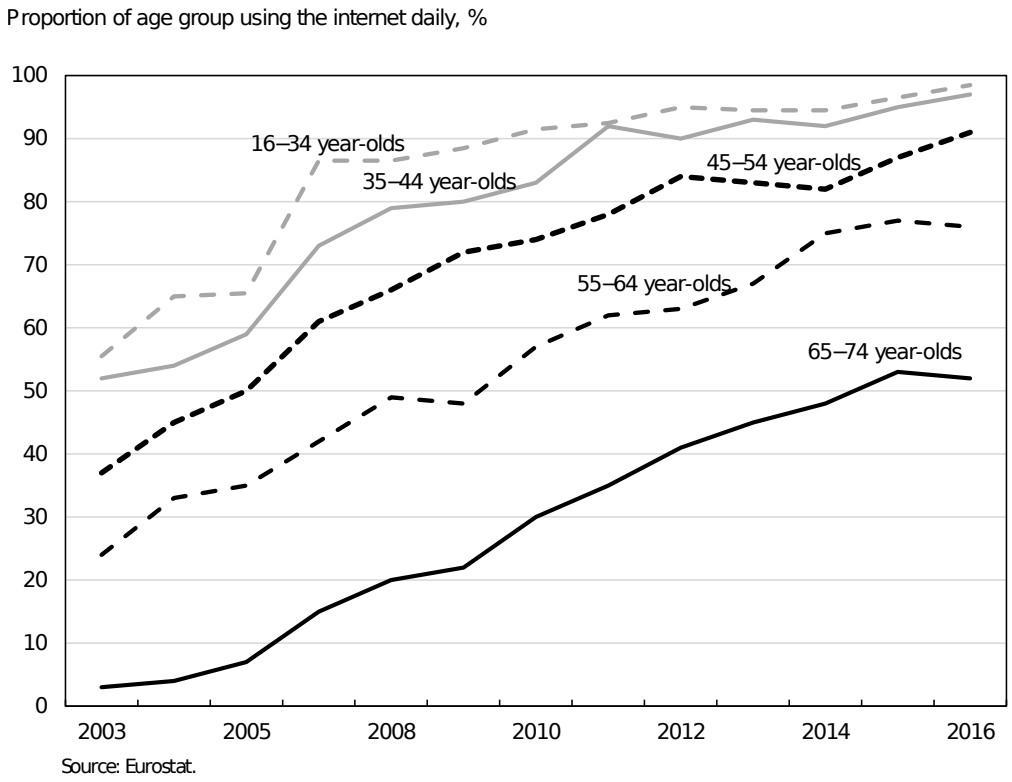


Figure 4: Sales of digital recordings

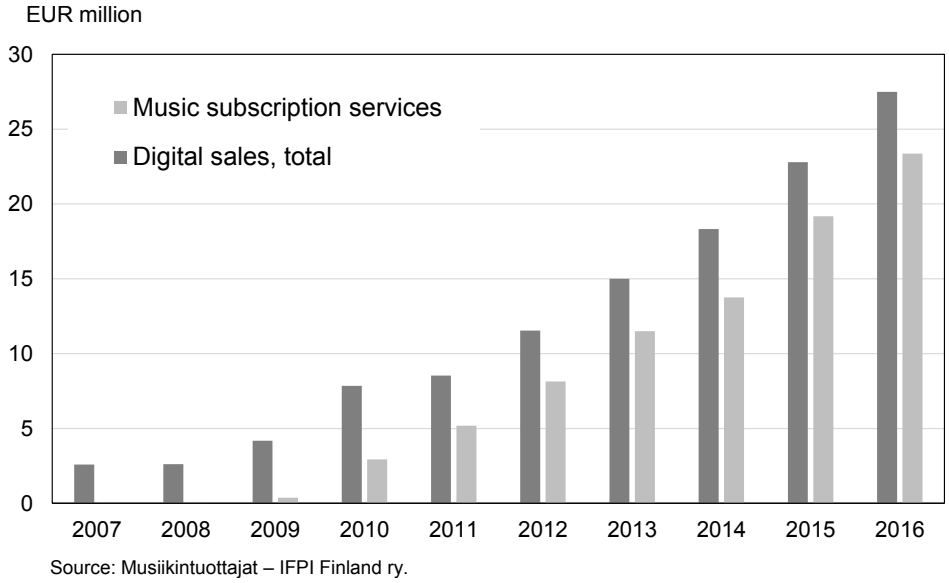
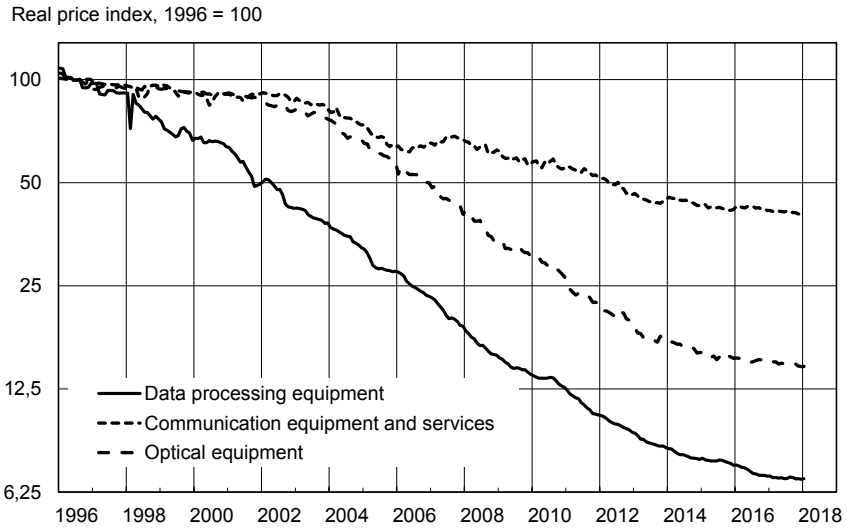
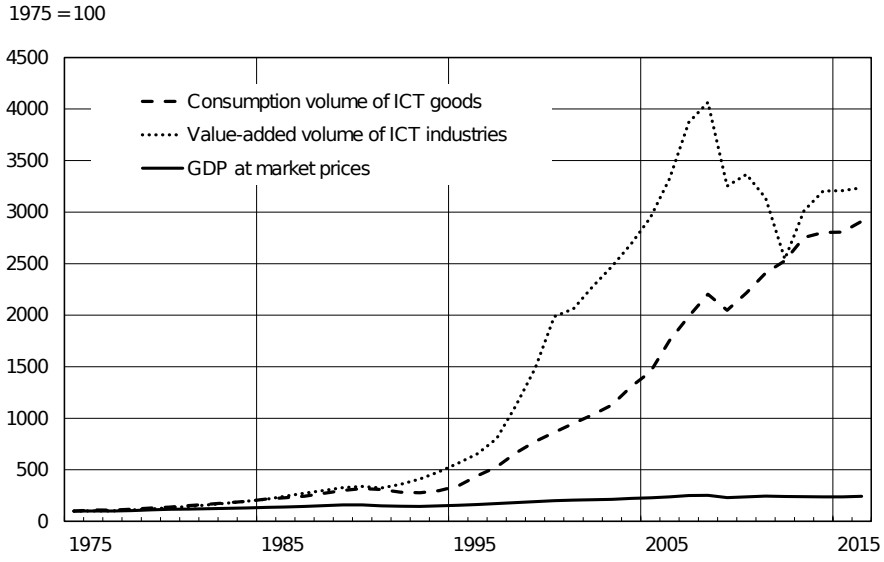


Figure 5: Consumer prices for information technology



The real price index measures quality adjusted change in comparison to average price level.
Source: Statistics Finland.

Figure 6: Volume of ICT production and consumption



Source: Statistics Finland.

Figure 7: ICT goods' share of households' actual individual consumption

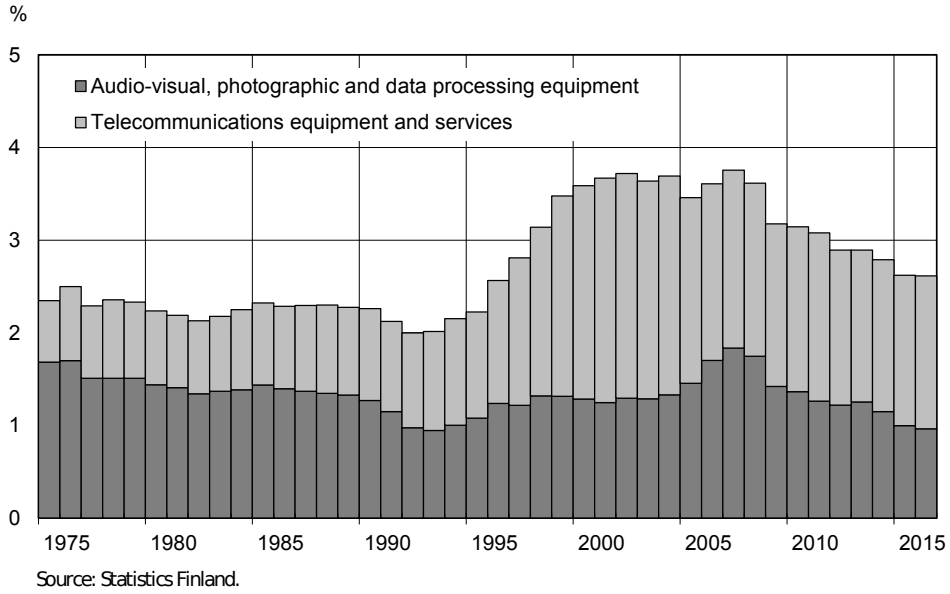
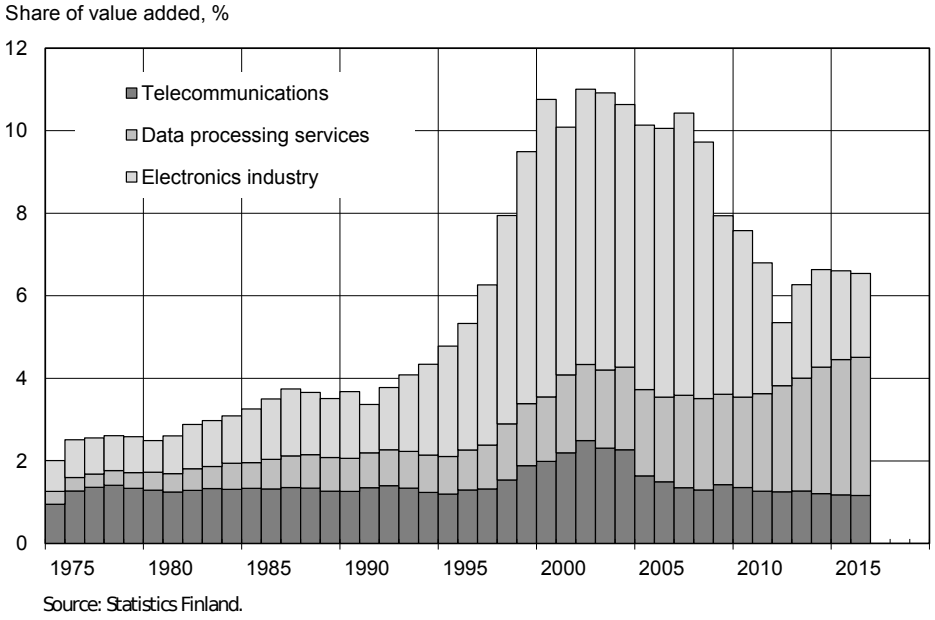


Figure 8: Share of ICT industry and services of value added



development and economic growth.

3.1 Size and structure of the economy

3.1.1 Gross domestic product

Gross domestic product (GDP) measures domestic production and it is the most commonly used metric for the size and development of a national economy. It is part of the national accounts, which is an extensive, internationally harmonised statistical system. In the national accounts, production refers to activity that uses labour, capital and intermediate products as inputs to produce goods and services. GDP can be calculated in three conceptually equivalent ways. Firstly, GDP measures the value added produced by various economic activities in the economy. Secondly, GDP measures the income generated by production (particularly employee compensation and capital income). Thirdly, GDP measures the monetary market value of goods and services produced for final use.

GDP is not a measure of well-being in the sense that it would alone enable comparison of well-being between different times or countries. GDP is, however, strongly intertwined with many factors essential to well-being and is therefore an important component in assessing well-being (Pohjola 2013, Jones and Klenow 2016). GDP does not attempt to capture income or wealth differences, the variety of goods, consumption of natural resources, the state of the environment, sustainability of the economy, population health, criminality nor possible increases in leisure time, even though these matter to the well-being of individuals (Stiglitz et al. 2009, Prime Minister's Office 2011).

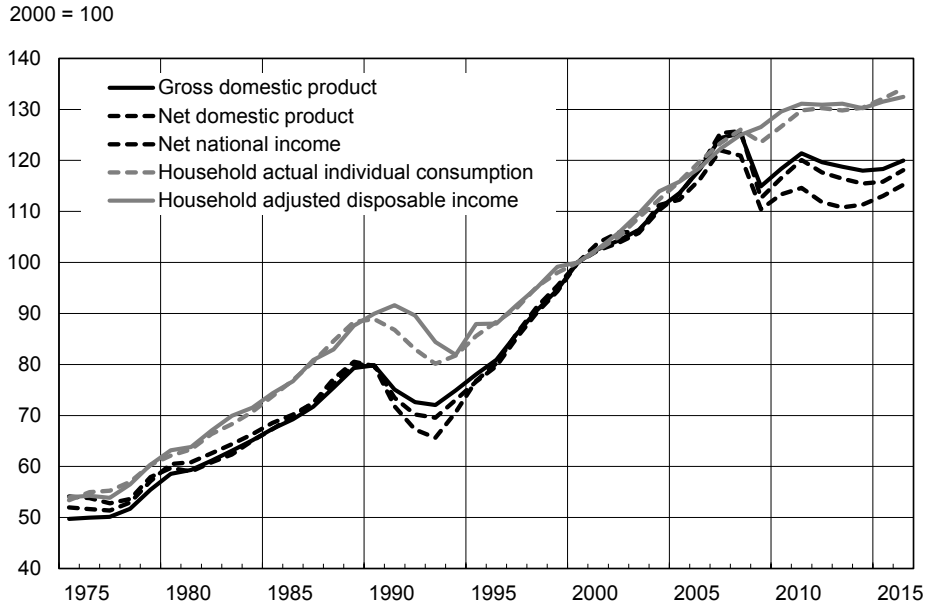
GDP per capita measures the average value of goods and services available to people. In this way, GDP can be used as a measure of the economic standard of living. Adjusted for purchasing power, it is also suitable for comparing the standard of living between countries.

The various components of GDP can be used to assess the structure of an economy (e.g. the relative size of economic activities and sectors). Nominal GDP is also used as a benchmark in many public finance metrics (e.g. debt ratio and tax ratio).

GDP is generally used as a measure of economic growth.[2] In order to assess real production growth, one must also be able to measure the development of prices. Nominal GDP is calculated using the price prevailing in each time period, so GDP growth can be due to rising prices. Real GDP, on the other hand, measures the development of the quantity and quality of production, which is not attributable to price changes. Changes in the quality and quantity of goods can often not be observed directly; we have to deduce these changes from changes in nominal GDP by eliminating the impact of price changes.

[2] In economics, economic growth is also often understood as an increase in production opportunities created by technological development, which can be described as potential GDP growth.

Figure 9: Key metrics in the national accounts



Source: Statistics Finland.

3.1.2 Alternative measures of the size of the economy

The national accounts also include other metrics like GDP that describe overall economic development and are suitable for similar kinds of analyses as GDP (Figure 9). Through digitalisation, greater emphasis has been given to the utility of these metrics in capturing the state of the economy.

Net domestic product is obtained by subtracting the consumption of fixed capital from gross domestic product. Net domestic product is useful in conditions where major changes are taking place in the size and structure of the capital stock. Net domestic product describes how much is available for consumption and expansion investments.[3]

National income, in turn, is obtained by adding net foreign primary income, such as employee compensation and investment income, to net domestic product. It describes how much income remains for domestic actors after imputed replacement investments. National income is a useful metric in conditions where there are significant international movements of capital and labour.

Alongside the above-mentioned metrics, the development of the standard of living can be measured by limiting examination to household consumption and income. Households' so-called actual individual consumption is a metric that includes, in addition to household consumption expenditure, services provided by the public sector and non-profit organisations, such as education and social and health services, that can be considered to serve individual

[3]Weitzman (1976) has shown theoretically that net domestic product is also a good substitute for the discounted present value of future consumption.

households directly. In a similar way, the supplemented income concept, household adjusted disposable income, captures well household income development, in which welfare services in kind received from the public sector are also taken into account.

Metrics restricted to households do not necessarily say much about the sustainability of development, which weakens their usability. Household consumption may be temporarily higher than income if it is financed by reducing net wealth. Household income development may also diverge temporarily from national income development if other sectors transfer more income to households. For example, in Finland in recent years, consumption growth has been partly financed by household and public sector borrowing and by reducing investment, which weakens consumption potential in the long term.

3.1.3 Problems in measuring the size and structure of the economy

Missing production

The usefulness of GDP as a measure of the size of the economy or of material living standards is somewhat limited by the fact that some of the activities producing economic value are not counted in the statistics. In the national accounts, the production boundary determines when an activity aimed at producing goods and services is included in the statistics.[4] If digitalisation leads to a significant share of output not being recorded in the national accounts, statistics may give a misleading picture of the volume and structure of economic activity.

In the national accounts, production does not include (apart from a few exceptions) own-account production of services by households or free digital services. GDP does not include, for example, cleaning one's own home or writing blog posts. Production also excludes free goods of nature (clean air) or growth of natural resources without labour input (growth of protected forests). Estimating a monetary value for such items would be uncertain, laborious and in many cases impossible.

New goods created through technological development might not be counted in the statistics. The characteristics of traditional goods may also change so that the goods are either excluded from the statistics or included within them.

Digitalisation has created many new services that are left outside of economic statistics because they are free. For example, the value of content produced by consumers for others in social media is not directly captured by the statistics. Free services financed by advertising, such as blogs, are only captured via advertisement-related cash flows. In the national accounts, a blog writer's output consists of the advertising revenue the writer receives, but at the same time the advertising expenditure of the company whose products are being advertised is deemed to be intermediate consumption. In GDP, these items offset each other. Advertisement-financed free services increase GDP only if they boost consumption of the advertised products without decreasing other consumption. The impact of free services on

[4]The basic principles of the production boundary in the European System of National and Regional Accounts (ESA 2010), applied in the EU, are set out in Regulation 549/2013 of the European Parliament and of the Council.

GDP is therefore modest. The accounts do not take into account the actual service produced for consumers, i.e. the blog itself, which as a free product does not have an easily measured monetary value. The problem is not in itself new; it has previously been associated, for example, with commercial television and free newspapers.

The distinction between recorded and unrecorded production is in many respects based on the practical preconditions for the compilation of statistics. From some perspectives, it is therefore justified to also consider a broader concept of output. For example, when assessing the impact of digitalisation on the standard of living, it may be worth taking into account output of goods and services that is not included in the official gross domestic product. Deficiencies in the coverage of the national accounts have also been supplemented and elaborated with satellite accounts aimed at estimating activities falling outside the scope of the official national accounts using comparable concepts and methods. These can be used to calculate an extended GDP that is not adversely affected to the same degree by the bias caused by the narrowness of the production boundary.

In Finland, satellite accounts have been prepared for household production (Varjonen and Aalto 2010), tourism (Finpro 2017) and culture (Statistics Finland 2017). For example, the satellite account for household production aims to estimate the monetary value of housework (cleaning, cooking etc.) on the basis of time-use, consumption and wage statistics. In 2006, it was estimated that adding household production to GDP would increase GDP by up to 39%.

It is not meaningful, however, to include absolutely all goods-producing activities in extended GDP. For example, it is not necessarily useful to consider hobbies as production even if they generate products of some sort. When examining the economy, one is typically restricted to measuring activities that can, in principle, be carried out by some other person without substantially changing the result.

Broadening the concept of GDP is not always appropriate, however. GDP can be used to reflect the funding base of the public sector, i.e. economic activity that could, in principle, be used to gather tax income for the funding of public expenditure. The official GDP is well suited to this purpose. Taxes can be levied more easily on, for example, cleaning services purchased by households (included in GDP) than on cleaning one's own home (not included in GDP).

If, however, there are items missing from GDP that would merit inclusion, then the tax ratio and expenditure ratio (public sector expenditure in ratio to GDP) as well as the public sector deficit and public debt will be overstated. EU membership fees, for example, are partly based on the gross national income of the member states, so measurement accuracy may have an impact on the fee contributions if there are systematic differences in statistical errors between countries. For the same reason, there are economic policy considerations associated with determining the production boundary.

The observed gross domestic product may also understate the actual scope of production when services previously regarded as production become free due to digitalisation and are therefore no longer recorded in the national accounts. Digitalisation has enabled self-service to become more common in many sectors, and thereby some of the activities are changed into own-account production of services by households and thus fall outside the production

boundary.

For example, the internet has made it easier to plan travel and book tickets, which has reduced the value added of traditional travel agencies. Similarly, the previously common printed encyclopaedias were reflected in the national accounts, but the free Wikipedia articles are not. Technological change may therefore be reflected in GDP as a reduction in the size of the economy, even though from the consumer's perspective a corresponding product is still available. Digitalisation might, on the other hand, shift some traditional household work to within the scope of the measured economy as it facilitates the activities of small companies and the carrying out short-term working tasks.

In most cases, however, free services to the consumer are funded by advertising income, for example. In such cases, the income of the company providing free email or WhatsApp is reflected in the GDP of the company's home country. These services are not, however, visible as consumption expenditure in the national accounts of the consumer's home country, unlike traditional letters and text messages. The same also applies to companies producing travel reservation platform services, for example.

If part of production becomes advertising-financed, it will affect the distribution of value added between economic activities and sectors. Measurement issues with digitalisation are particularly heightened in ICT-related service sectors that produce a large range of free digital services. The importance of the ICT sector to the economy is probably significantly greater than may be inferred on the basis of consumption. The global market for services makes measurement even more difficult.

Consumption, intermediate consumption and investment

Digitalisation may make it difficult to separate investment from consumption and intermediate consumption. The distinction has an impact on the magnitude of gross domestic product and the timing of net domestic product. In the national accounts, investment – i.e. gross fixed capital formation – refers to acquisitions of fixed assets less disposals. Fixed assets are goods produced as outputs from processes of production that can themselves be used in the processes of production for more than a year.

In public debate, the idea has often been raised that the data accumulating in companies' information systems should be interpreted as capital. So interpreted, data could be recognised in the national accounts as fixed assets and its accumulation as investment. In the digital economy, data are often a key factor of the production for companies, and companies can utilise in their production the data accumulated in their customer databases for a long time (more than a year).

Data are already visible in the national accounts insofar as their collection, processing and use require inputs (servers, database and analytics software). Data may also be evident in companies' output if they increase sales and improve product quality.

If a larger proportion of intermediate consumption is interpreted as investment, the value of GDP will rise. If companies' data are interpreted as capital, investment in their accumulation will be recorded in GDP. Alternatively, data may be interpreted as part of the production

process (like paper notes or documents) or as an intermediate product that is rapidly consumed in the production process (less than a year).

In net domestic product, the impact of the distinction between intermediate consumption and investment is less significant, because it also takes into account consumption of capital. In net domestic product, the distinction mainly affects the timing of value added formation. Changing the recognition from intermediate consumption to investment will increase the net domestic product at the time in question, but will reduce it by the same amount in the future as capital is consumed.

In the case of households, drawing the line between consumption and income generation may become more difficult. Platform and sharing economy services are becoming more common and are facilitating the participation of households in production activities. It is possible that the goods acquired by households will be used more for income generation. In that case, some of the goods acquired for production might erroneously be recognised in the national accounts as consumption instead of intermediate consumption or investment. For example, a car acquired by a household is recognised in the accounts as consumption, but as part of business activity practised in the platform economy it should be interpreted, at least in part, as an investment.

Consumption and movements of intangible assets

Digitalisation is evident in the growing significance of intangible assets. The national accounts recognise intangible property products, consisting mainly of capital accumulated by research and development and of computer software and databases.

The depriciation rate of intangible assets is significantly faster than that of buildings or machinery and equipment. As the proportion of intangible assets in the capital stock increases, the average rate of consumption of the capital stock accelerates and the difference between gross and net domestic product grows.

In conditions where the structure of the capital stock is changing significantly, net domestic product reflects better than GDP the amount of output available for consumption and productive investments. Use of net domestic product, on the other hand, is limited by the fact that the imputed estimate of capital consumption is imprecise and calculation methods might differ between countries.

In the global economy, the transfer of intangible assets from one country to another is easier than before due to digitalisation. For multinational companies engaged in digital business, software, patents and brands are key factors of production. Multinational companies can affect a small country's GDP figures significantly by transferring their intellectual property rights to the ownership of a subsidiary located in another country (Guvenen et al. 2017, Statistics Finland 2017). Intellectual capital revenue and consumption are reflected in the accounts of the country where the subsidiary that owns it is registered. For example, Ireland's GDP grew by more than 25% in 2015 when multinational companies moved property to the country (Taskinen 2016).

Changes in GDP arising from transfers of intangible assets between countries do not reflect well the income development of a country's citizens. In conditions where intangible assets

movements are large, national income is better suited to capturing general economic development. National income takes into account the rapid consumption of intangible assets as well as the income streams arising from capital that belong to foreign owners.

3.2 Price indices

The meaningful comparison of monetary quantities at different points in time requires the use of price indices.[5] Price indices measure general movements in the level of prices and can be used to separate, in changes in nominal measures, the impact of a rise in prices from actual real economic factors. For most items, real GDP growth must be calculated by excluding the effect of price changes from nominal GDP growth. There are a variety of price indices for different purposes: the consumer price index (CPI) measures changes in prices of goods consumed by households, while the producer price indices measure changes in prices of outputs and intermediate goods. There are also specific price indices for imports and exports.

Price indices capture the general price development of a specific set of goods, i.e. they summarise in one weighted average figure information on the price changes of a set of goods. In the case of the CPI, for example, weights are assigned to each product corresponding to its share in household consumption expenditure.

In assessing the development of well-being, a meaningful price index will correspond as closely as possible to a cost-of-living index that measures the relative amount of money required to achieve the same utility level at different points in time.[6] A cost-of-living index shows how much more nominal income is needed at a point in time – after changes in prices, quality and goods selection – to buy a basket of goods that provides the same utility level as before.[7] A cost-of-living index therefore makes it possible to calculate the extent to which growth in nominal income has benefited the consumer.

A cost-of-living index so defined differs from a fixed-weight CPI because consumers can react to price changes by adjusting the consumption shares of goods and thereby improve their utility level.

Price indices aim, in principle, to measure 'pure' price developments, i.e. keeping the quality of goods and services constant. In other words, the aim is to compare, at different points in time, the prices of goods that are equal in terms of their quality and other characteristics.

[5] This analysis disregards so-called price level indices, which measure the price level of different countries and allow the comparison of nominal quantities between countries.

[6] The cost-of-living index (elinkustannusindeksi) should not be confused with Statistics Finland's statistics of the same name, which follow the consumer price index.

[7] Consumer i's cost-of-living index $COLI_{t,i}$ is the minimum consumption expenditure at time t that is needed to achieve the same utility level as at time 0, relative to the consumption expenditure at time 0, i.e.

$$COLI_{t,i} = \frac{e_i(u, p_t)}{e_i(u, p_0)},$$

where e_i is the consumer i's expenditure function, u the utility level, and p the price vector. A corresponding index can be made for producer prices as a ratio of cost functions.

If a price increase of a product is solely due to an improvement in quality, an index that measures pure price developments should not rise.

The challenges brought by digitalisation to the measurement of price developments are examined below. Digitalisation creates new goods and transforms existing ones in ways that pose challenges for those who prepare price indices. Digitalisation has been particularly reflected in an improvement in the quality and a fall in price of ICT goods.

The measurement challenges associated with price indices have long been known (Boskin et al. 1998, Hausman 2003, Statistics Finland 2016). Key factors causing measurement errors include substitution bias related to the index formula, erroneous estimates in the weight structure, new goods, outlet sampling bias and quality bias.

Substitution bias

The difference between the consumer price index and the cost-of-living index is called the substitution bias. The cost-of-living index takes into account that consumers may, after prices change, replace goods with others. The fixed weights traditionally used in price indices therefore give a biased picture of the consumer's status. If, for example, consumers are indifferent to different varieties of apple and the price of a single variety rises, they may switch to consuming other varieties without their consumption expenditure growing or their utility level falling. It can be shown theoretically that, due to substitution bias, Laspeyres-type price indices always overstate consumer inflation compared with a cost-of-living index.[8]

Substitution bias is also reflected in producer price indices. Like consumers, companies can replace intermediate products with cheaper alternatives when individual prices rise. Similarly, a company can increase the value of output by favouring, in its production, goods whose price has risen. In the case of a company, substitution bias overstates the price developments of intermediate goods and understates the development of input prices. As a result of this, the national accounts might understate the development of intermediate goods volume but overstate the development of output volume. Insofar as the same producer price indices are applied to both the consumption and supply of intermediate goods, the biases associated with both cancel each other, in which case they have no impact on value added on the level of the economy as a whole. In the case of domestic intermediate goods prices, therefore, substitution bias mainly means that economic growth is allocated erroneously between economic activities.

Structure of goods basket and new goods

Calculating an appropriate price index requires that the content of the goods basket on which it is based has been chosen and measured correctly. The above-mentioned measurement problems associated with the structure of the economy are therefore also reflected in price indices.

The variety of new goods created as a result of digitalisation pose a significant challenge. New goods are included in the sample of a price index with a time lag, and therefore changes

[8]Consumers' consumption expenditure cannot rise more than a Laspeyres index, because they can always choose the previous year's basket of goods used as weights in the Laspeyres index at the price shown by the index, but in some cases they may, by changing the proportions of goods, end up in a better situation.

are not initially reflected in the development of the index. This problem is alleviated by the fact that, initially, the weight of new goods in the basket is often small, and thus their effect on the index is minor. If, however, there are large changes in prices and rapid growth in consumption share, the effect could also be reflected in the overall index. The introduction of a chain index formula has helped mitigate this problem in the CPI and in the national accounts deflators.

New goods should be taken into account in the cost-of-living index insofar as their entry into the market increases the consumer surplus (Boskin et al. 1998).[9] Growth of the consumer surplus should be taken into account because through new goods the consumer may achieve the same utility level at a lower cost. Through new goods, the consumer's situation may improve, even though the prices of old goods or the consumer's nominal income do not change. In practice, producing a cost-of-living index is difficult, because it requires the estimation of consumers' utility functions. Broda and Weinstein (2010) estimated, with the aid of detailed consumption data, that in the USA new goods cause a 0.8 percentage point upward measurement bias in the CPI. The estimate is subject to many reservations, but the calculation indicates the significance and possible scale of new goods (Aghion et al. 2017) New free digital services should also be taken into account in price indices in the same way as other new goods. The cost-living-index falls (as opposed to the CPI) because, through new free goods, the consumer can achieve the previous utility level at lower cost (Hausman 2003). When a new product is free, the consumer's surplus is higher than with a paid-for product.

Goolsbee and Klenow (2006) estimate, based on consumption and time-use data, that the consumer surplus generated by use of the internet was around 2–3% relative to income in the USA in 2005. This estimate, too, is subject to many reservations and is at best indicative. It should be noted that the use of the internet, and of mobile devices in particular, has increased considerably since 2015 (see also Brynjolfsson and Oh 2012).

Digitalisation has changed the nature of many products from goods into services. For example, in addition to compact discs, consumers can now also subscribe to streaming services and access a vast music library instead of individual albums. If these are interpreted as separate products, the improvement brought by streaming services will not be reflected in the CPI. Price changes of a new product are only reflected in the price index after it is added to the goods basket.

For many consumers, streaming services and CDs are basically the same product, whose price has fallen and quality improved. From a consumers' perspective, the same music content is now available at a lower price and as part of a service that facilitates their listening to the music. If CDs and streaming services were considered to be the same product, the price index should fall and consumption volume increase, as long as the change in quality can be properly assessed. Similar problems are associated with, for example, film streaming services, digital books and newspapers, and platform-economy accommodation services.

Outlet sample bias

[9]Strictly speaking, it is a compensatory variation, but the consumer surplus approximates this well (Hausman 2003).

The selection of outlets and companies in the price index sample may cause bias if the level or development of prices differ between outlets. Bias may also arise if the sample is not sufficiently representative or consumption shares between outlets have not been estimated correctly. The increasing popularity of online shopping and discount stores in recent decades has presumably caused an upward bias in price indices.

Digitalisation reduces the significance of location and distances, which can improve the substitutability of goods between purchasing sites, thereby amplifying the outlet sample bias. In the CPI, goods indices consist of a weighted average of regional microindices that, in turn, are based on price changes within the sales outlets selected for the sample. If it is easier than before for consumers to change shopping venue when prices change, the upward bias in the CPI may be amplified. If, for example, an outlet increases the price of a product and the consumer has the opportunity to buy the same product from an online store at a lower price, actual living costs will not rise to the extent indicated by the CPI.

The same products may be interpreted as being different in quality depending on the shopping venue, because traditional brick-and-mortar stores, discount markets and online stores differ from each other in terms of customer service and experience. Purchases made in an online store, for example, may be considered to be of lower quality if the advice given in a sales outlet and the opportunity to try the product are interpreted as being part of the product's features. New lower-priced shopping venues do not therefore reduce "pure" prices if behind the lower prices is poorer overall quality. The shift in consumption to cheaper shopping venues suggests, however, that the consumer surplus has grown and that, at least in this respect, the change should also be reflected in the cost-of-living index (Hausman 2003).

The price indices of imported intermediate goods also contain an upward bias, which corresponds technically to the outlet sample bias in the CPI. Through the globalisation of production value chains, this bias has increased and led to an understatement of volume growth (offshoring bias). This, in turn, exaggerates growth of domestic real value added and domestic productivity growth. Houseman et al. (2011) estimate that, for this reason, value added growth of manufacturing industry in the USA has been measured 0.2–0.5 percentage points lower in the period 1997–2007. In the electronics industry, the bias would explain up to 20–50% of productivity growth. ICT industry prices, on the other hand, also contain bias factors resulting from quality correction that have an opposing impact (Byrne et al. 2017).

Impact of improving the quality of statistics

Improving the accuracy and quality of statistics may paradoxically also result in bias in economic metrics when comparing developments over time and between countries. Statistical methods are constantly being developed and improved, making the statistics more accurate and less biased. If measurement errors are different in different statistics, comparison of statistics may be adversely affected.

For example, before 2013 the weight structure of the CPI was updated in Finland at five-year intervals, while nowadays it is updated annually. Presumably this reduces the upward substitution bias associated with the Laspeyres index. Similarly, outlet sampling has been reviewed annually since 2013, which has presumably reduced the outlet sample bias. Also, the introduction of new statistical production methods (e.g. hedonistic models) and data

sources (online store price databases and scanner data) may also reduce measurement errors in the future. In principle, it is possible that the slowdown in inflation in recent years is partly due to the fact that the upward statistical bias has diminished over time.

Comparability of statistics between countries might deteriorate when new tools are introduced in statistics production at different rates in different countries. Although the structure and content of the Harmonised Index of Consumer Prices in Europe have been harmonised for a long time now, production methods may differ considerably between countries.

Changes in quality

Price indices are formed by comparing, at different points in time, the prices of goods that are equal in terms of their quality and other characteristics. It is challenging to hold the quality of goods and particularly services constant if it is not possible to find goods that are fully comparable or to identify similarities at different points in time. If the same product is no longer found on the market, an effort is made to find for comparison a similar product or to assess the effect of different characteristics on the price.

For example, car and computer models change rapidly and there may be significant differences between the various models. In addition, services are tailored, and it may be difficult to recognise similarities and any changes in quality. With digitalisation, production processes become more flexible and logistics more efficient, which makes it even easier to expand and tailor the selection of goods and services.

Advertising is often used to try and increase the value of the products to the consumer, enabling a higher price to be charged for the products. If the price premium generated by advertising is interpreted as a pure increase in prices, real GDP does not grow. Alternatively, it may be thought that the willingness resulting from advertising to pay a higher price for a product reflects an improvement in quality. In such an interpretation, the price increase caused by advertising should not be reflected in price indices describing pure prices; it should be reflected in a real GDP growth. As stated above, advertisement-financed free digital services increase nominal GDP only if they increase the prices or volume of the advertised products. Such growth is not, however, fully reflected in real GDP, because in practice the price premium is not interpreted as an improvement in quality. Making such a quality correction to price indices would be very challenging.

Digitalisation has facilitated the partial transfer of service production to consumers (e.g. travel planning, banking services), which has lowered prices. If such a fall in prices is interpreted as a deterioration in quality, it should not be reflected fully in the price index.

3.3 Economic growth

Estimates of the real growth rate of the economy are largely based on estimates of the development of nominal GDP and prices. In order to measure the growth rate of the economy correctly, one must also be able to measure the value and prices of output sufficiently accurately.

The measurement error associated with extended GDP growth rates can be divided analytically into three components. The observed growth rate of real GDP deviates from the growth rate of extended GDP if (1) the development of nominal GDP or (2) price indices are measured incorrectly or if (3) the growth rate of unobserved GDP deviates from the growth rate of observed GDP.[10] Even though some production is not counted in the statistics, this does not necessarily cause a bias in the growth figure. If unrecorded GDP grows at the same rate as recorded GDP, extended GDP also grows at the same rate as the recorded economy.

The above-mentioned aspects relating to digitalisation point above all to the fact that unrecorded GDP has probably grown faster than recorded GDP and that the rise in prices indices has, in turn, been overstated. It is justified to assume that extended GDP growth has been somewhat faster than observed growth.

Measurement errors associated with real GDP matter less when monitoring economic cycles than when assessing long-term trends (Feldstein 2017). Measurement errors do not make it difficult to observe trend deviations in growth rate if the magnitude of the measurement bias is independent of cyclical conditions. If, however, the bias is pro- or counter-cyclical, this may result in erroneous conclusions about economic conditions. New goods are created more during economic expansions, and therefore the official GDP may understate the strength of cyclical fluctuations (Broda and Weinstein 2010). On the other hand, the cyclical fluctuations of output not recorded in the national accounts are weaker than fluctuations in official GDP. For example, own-account production of services by households (such as home cleaning and cooking) are largely independent of economic conditions, making the development of extended GDP smoother than official GDP (Koistinen-Jokiniemi et al. 2017).

3.4 Impact on other economic metrics

Measurement errors caused by technological development might also be reflected in many other key economic metrics, such as productivity, real incomes, public sector metrics and income distribution.

In productivity growth metrics, value-added growth rate measurement errors are directly visible. Productivity growth can be measured by the growth in labour productivity, i.e. by comparing the development of GDP against the development of hours worked. Digitalisation also poses challenges for evaluating actual hours worked by blurring the boundary between work and leisure.

Productivity development can also be examined by measuring the development of total factor productivity, meaning output growth, which is not explained by growth in the number of

[10] Let $Y_t^* = Y_t + U_t$ be extended real GDP, where Y_t is its observed and U_t its unobserved component. Let it be noted that $Y_t = A_t/P_t$, where A_t is nominal GDP and P_t its price. The relative change in extended GDP from the previous year can be presented as the approximate decomposition

$$\frac{Y_t^* - Y_{t-1}^*}{Y_{t-1}^*} \approx \frac{Y_{t-1}}{Y_{t-1}^*}\left(\frac{A_t - A_{t-1}}{A_{t-1}} - \frac{P_t - P_{t-1}}{P_{t-1}}\right) + \frac{U_{t-1}}{Y_{t-1}^*}\frac{U_t - U_{t-1}}{U_{t-1}}$$

, where growth depends on observed nominal GDP growth, price growth and unobserved GDP growth.

factors of production or by changes in their structure. It has been noted that the acquisition of digital assets to some extent interpreted as investments might not be counted in statistics, which may lead to an understatement of capital stock. The impact on the total factor productivity growth rate of the scope of the statistical recording of digital investments is not clear, however. For example, recognising as an investment the expenditure used to accumulate companies' data would, on the one hand, increase GDP but would, on the other hand, reduce total factor productivity (i.e. the part of economic growth that is not explained by the growth of inputs). In addition, in calculating total factor productivity, it should be taken into account that as the proportion of rapidly depreciating and increasingly cheaper capital (such as computers and software) grows, the net stock in the national accounts understates growth of capital input (Pohjola 2017). With more comprehensive and more detailed statistics on digital capital, the factors affecting productivity could be better understood.

Literature examining the slowdown in productivity growth has considered the significance of measurement problems associated with the production and use of ICT goods. Is it possible that the impact of ICT inputs on productivity growth has been understated due to measurement errors? Byrne et al. (2016) estimate that measurement errors are not significant enough to explain the slowdown. In addition, with the contraction of the ICT industry in recent years, the significance of errors should have declined. Similarly, Syverson (2017) found no indications of measurement errors so large that would completely explain the slowdown in productivity growth. Syverson estimates that measurement errors related to digitalisation could explain at most one third of the slowdown in productivity growth observed in the USA since 2004.

The bias associated with the CPI is inversely reflected in the development of real incomes. Sacerdote (2017) examines the effect of the bias associated with consumer price indices in the USA and estimates that the development of real wages and incomes has been faster than estimated in recent decades, if the upward bias of the price indices is taken into account.

Measurement errors do not significantly affect the estimate of the sustainability of public finances. In the sustainability gap, understated real rate of interest and economic growth due to overstated inflation affect the discount factor in opposite directions. Correspondingly, if the understatement of GDP leads to an overstatement of financial balances, these surpluses and deficits will impact the sustainability gap metrics in different directions.

Measurement errors in price indices also directly affect various index-linked allowances and income transfers.[11] Overstating price developments leads to faster than intended growth in index-linked income transfers. It should be noted, however, that a measurement error in a price index does not affect development of the ratio of income transfers and earnings, if their nominal development has been correctly measured. The interpretation therefore depends on whether indexing is intended to maintain the real value of the benefits or their ratio with respect to general income development.

Measurement errors may also affect estimates of consumption and income differences. If free digital services are available to all, regardless of income level, differences in consumption

[11] This concern was at the time a key reason for the establishment of Boskin Commission (Boskin et al. 1998).

expenditure are reduced. In accounting terms, consumption of free services can be interpreted as a contribution in kind, in which case the household is considered to receive income corresponding to the value of the consumed product. In some respects, the uneven distribution of the benefits and disadvantages of digitalisation may also exacerbate effective consumption differences. There may be large differences in people's ability or desire to consume unmeasured digital services. Similarly, consumers who are accustomed to services displaced by technological development may suffer from change (e.g. due to a decline in banks' branch network).

In advanced economies, economic conditions have been exceptional in many ways over the past ten years. Productivity has slowed, investment has fallen, inflation has remain below target, real rates of interest have trended downwards and GDP development appears to have permanently declined from the trend that preceded the financial crisis (Kilponen 2015, Haavio 2016, Itkonen and Obstbaum 2016, Ciccarelli and Osbat 2017, Adler et al. 2017).

An explanation for these phenomena has been sought in measurement errors, besides other factors. To some extent, measurement errors are associated with all of the above-mentioned phenomena. Based on the earlier examination of indicators, it can be considered probable that in reality the level of nominal GDP is somewhat higher, inflation lower, the real rate of interest higher and economic growth faster than what is observed in statistics. If real GDP had in reality grown faster than measured, then productivity growth would also be faster than measured.

Reconciling long-term low inflation and measurement errors is challenging, however. If the real increase in prices had been lower than measured, then inflation in recent years would have been clearly negative in many economies and therefore even further from current inflation and price stability targets. Deflation encourages the deferral of consumption and a higher real rate of interest increases the financial cost of investment, which could explain the weakness in total demand. It should be noted, however, that nominal wage development, with which similar measurement problems are not associated, has not started to decline, so at least in Finland there is no sign of an actual deflation spiral. An inflation measurement error does not substantially affect estimates of debt sustainability, because the error is reflected in growth of real rates of interest and real incomes.

The prevailing view among researchers would appear to be that the problems associated with measurement cannot fully explain the unusually long-lasting slow growth of recent years.

4 Conclusions

It is not a simple or easy task to build an overall picture of a national economy. The challenges associated with measuring the economy have always been considerable. Digitalisation is reshaping the economy and society in many ways, which creates new problems for those who produce and interpret statistical data.

The current central framework and concepts of the national accounts are largely relevant and accurate in capturing economic output, income formation and consumption. The bulk of

output can be measured appropriately. As digitalisation advances, however, the economic structure is increasingly focused on goods for which it is difficult to estimate changes in quantity, quality and prices. Classifications of economic industries and products are ill suited to assessing digital structural change, since ICT has already become part of almost every aspect of economic activity, just as electricity did in the past. As part of ongoing statistical development, more attention should be devoted to digitalisation.

Developments in well-being should be assessed using diverse metrics. There is, however, a strong connection between metrics depicting the economy and developments in well-being. It is possible that this connection will weaken to some extent with technological advances, since the impact of digitalisation in improving living standards is not fully reflected in economic statistics. It is not appropriate to assess developments in well-being solely using economic metrics, but neither should we do so without them. Besides GDP, the national accounts also include other metrics (such as net domestic product and national income) that capture overall economic development. Through digitalisation, greater emphasis has been given to the utility of these metrics.

The economic literature does not provide a commonly agreed method for estimating the magnitude of the measurement bias stemming from digitalisation. The general view among researchers would seem to be that it is difficult to give a precise estimate of the measurement biases associated with various metrics, but it is possible to estimate their direction fairly reliably. A comprehensive assessment of individual phenomena related to digitalisation can show the probable direction of measurement biases and reveal which factors are of sufficient magnitude to impact the overall picture of the economy.

New goods, free services, quality changes and global intangible assets are the most significant challenges associated with the measurement of digitalisation. Free services increase consumer well-being but are largely excluded from economic statistics. Quality improvement in ICT devices and services is very challenging to measure, and measurement errors may accumulate over time. Movements in global intangible assets can cause huge shifts in the level of GDP and related key figures.

Measurement errors probably explain part of the slowdown in productivity growth over the past decade, but they cannot be regarded as the sole reason. It is important to note, however, that measurement errors do not fundamentally change the view on public sector sustainability or cost-competitiveness. Unmeasured gains from digitalisation, such as free digital services, do not help to correct public sector deficits. In principle, we can assume that measurement errors are similar in competitor countries and therefore do not alter Finland's relative position.

When facing new measurement challenges, we should not draw the conclusion that statistics would be less valuable and meaningful in supporting decision-making. On the contrary, in a time of the rapid technological transformation, reliable information on the state of the economy and changes in economic structures is even more important. However, keeping economic statistics relevant in a changing world requires ongoing development. Digitalisation also brings new tools to the production of statistics, and we should make use of these tools. Information is vital for the functioning of the economy and the well-being of the public.

References

Adler, G., Duval, R., Furceri, D., Çelik, S.K., Koloskova, K. and Poplawski-Ribeiro, M. (2017), "Gone with the Headwinds: Global Productivity", IMF Staff Discussion Notes No. 17/04.

Aghion, P., Bergeaud, A., Boppart, T., Klenow, P.J. and Li, H. (2017), "Missing Growth from Creative Destruction", http://www.klenow.com/missing-growth.pdf (referenced 14.9.2017).

Ahmad, N. and Schreyer, P. (2016), "Measuring GDP in a Digitalised Economy", OECD Statistics Working Papers, No. 2016/07.

Bean, C. (2016), "Independent Review of UK Economics Statistics", HM Treasury, Cabinet Office, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/507081/2904936_Bean_Review_Web_Accessible.pdf (referenced 14.9.2017).

Boskin, M.J., Dulberger, E.L, Gordon, R.J., Griliches, Z. and Jorgenson, D.W. (1998), "Consumer Prices, the Consumer Price Index, and the Cost of Living", *Journal of Economic Perspectives* 12: 3–26.

Broda, C., and Weinstein, D.E. (2010), "Product Creation and Destruction: Evidence and Price Implications", *American Economic Review* 100: 691-723.

Brynjolfsson, E. and Oh, J.H. (2012), "The Attention Economy: Measuring the Value of Free Digital Services on the Internet", 33rd International Conference on Information Systems, Orlando, Florida.

Brynjolfsson, E. and McAfee, A. (2014), *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies*, WW Norton & Company.

Byrne, D.M., Fernald, J.G. and Reinsdorf, M.B. (2016), "Does the United States Have a Productivity Slowdown or a Measurement Problem?", *Brookings Papers on Economic Activity*, Spring: 109–157.

Byrne, D., Oliner, S. and Sichel, D. (2017), "Prices of High-Tech Products, Mismeasurement, and Pace of Innovation", NBER Working Paper No. 23369.

Ciccarelli, M. and Osbat, C. (2017), "Low inflation in the euro area: Causes and consequences", European Central Bank Occasional Paper Series, No 181.

Feldstein, M. (2017), "Underestimating the Real Growth of GDP, Personal Income, and Productivity", *Journal of Economic Perspectives* 31: 145–64.

Finpro (2017), "Matkailutilinpito: matkailun talous- ja työllisyysvaikutukset 2014–2015", Visit Finland tutkimuksia 8, http://www.visitfinland.fi/wp-content/uploads/2017/10/Matkailutilinpito_2014-2015.pdf?dl (referenced 12.10.2017).

Goolsbee, A. and Klenow, P.J. (2006), "Valuing Consumer Products by the Time Spent Using Them: An Application to the Internet", *American Economic Review* 96: 108–113.

Guvenen, F., Mataloni, R.J. Jr., Rassier, D.G. and Ruhl, K.J. (2017), "Offshore Profit Shifting and Domestic Productivity Measurement", NBER Working Paper Series No. 23324.

Haavio, M. (2016), "Pitkän hitaan kasvun kolme selittäjää", Euro ja talous, http://www.eurojatalous.fi/fi/2016/artikkelit/pitkan-hitaan-kasvun-ajan-kolme-selittajaa/ (referenced 14.9.2017).

Houseman, S., Kurz, C., Lengermann, P. and Mandel, B. (2011), "Offshoring Bias in U.S. Manufacturing", *Journal of Economic Perspectives* 25: 111–132.

Hausman, J. (2003), "Sources of Bias and Solutions to Bias in the Consumer Price Index", *Journal of Economic Perspectives* 17: 23–44.

Hellman, L. (2017), "Digitalisaatio ja uudet hyödykkeet hintaindekseissä", *Kansantaloudellinen aikakauskirja* 113: 531–541.

Itkonen, J. and Obstbaum, M. (2016), "Pitkän aikavälin kasvu tuottavuuden ja työllisyyden näkökulmasta", Euro ja talous 5/2016, http://www.eurojatalous.fi/fi/2016/5/pitkan-aikavalin-kasvu-tuottavuuden-ja-tyollisyyden-nakokulmasta/ (referenced 14.9.2017).

Itkonen, J. (2017), "Digitalisaation mittaushaasteiden vaikutus kansantalouden kokonaiskuvaan", *Kansantaloudellinen aikakauskirja* 133: 489–512.

Jones, C.I. and Klenow, P.J. (2016), "Beyond GDP? Welfare across Countries and Time", *American Economic Review* 106: 2426–2457.

Kilponen, J. (2015), "Hiipuvan kasvun lähteillä", *Kansantaloudellinen aikakauskirja* 111: 138–147.

Koistinen-Jokiniemi, P., Koskiniemi, T., Lehtinen, I., Lindroos, V., Martikainen, J., Montonen, S., Savela, O. and Tuomaala, E. (2017), *Digitalisaatio ja BKT - Miten digitalisaatio näkyy taloustilastoissa*, Tilastokeskus.

Kotiranta, A., Koski, H., Pajarinen, M., Rouvinen, P. and Ylhäinen I. (2017), "Digitalisaatio muuttaa maailmaa – tarvitaanko politiikan tueksi uusia mittareita?", Valtioneuvoston kanslian raporttisarja 2/2017.

Lequiller, F. and Blades, D. (2014), *Understanding National Accounts: Second Edition*, OECD Publishing.

OECD (2014), *Measuring the Digital Economy: A New Perspective*, OECD Publishing.

Pohjola, M. (2013), "Talouskasvu ja hyvinvointi", *Kansantaloudellinen aikakauskirja* 109: 5–12.

Pohjola, M (2014), *Suomi uuteen nousuun.* Teknologiateollisuus ry.

Pohjola, M (2017), "Tuottavuus, rakennemuutos ja talouskasvu 1975–2015", *Kansantaloudellinen aikakauskirja* 113: 463–488.

Sacerdote, B. (2017), "Fifty Years Of Growth In American Consumption, Income, And Wages", NBER Working Paper No. 23292.

Stiglitz, J.E., Sen, A. and Fitoussi, J-P. (2009), The measurement of economic performance and social progress revisited: Reflections and Overview, https://halshs.archives-ouvertes.fr/file/index/docid/1069384/filename/wp2009-33.pdf (referenced 14.9.2017).

Syverson, C. (2017), "Challenges to Mismeasurement Explanations for the U.S. Productivity Slowdown", *Journal of Economic Perspectives* 31:165–186.

Tilastokeskus (2016), * Kuluttajahintaindeksin käsikirja 2015=100 - käyttäjän käsikirja*, Käsikirjoja 39, Tilastokeskus.

Tilastokeskus (2017), "Kulttuurin satelliittitilinpito", http://www.stat.fi/til/klts/index.html (referenced 12.10.2017).

Taskinen, K (2016), "Voiko maan bkt kasvaa 26,3 prosenttia vuodessa?" Tieto & trendit -blogi, http://tietotrenditblogi.stat.fi/voiko-maan-bkt-kasvaa-263-prosenttia-vuodessa/ (referenced 11.10.2017).

Tuomaala, E. and Koskiniemi, T. "Miten digitalisaatio näkyy kansantalouden tilinpidossa?", *Kansantaloudellinen aikakauskirja* 113: 513–530.

Varjonen, J. and Aalto, K. (2010), "Kotitalouksien palkaton tuotanto ja ostopalvelujen käyttö", Kuluttajatutkimuskeskuksen julkaisuja 2/2010.

VNK (2011), Bkt ja kestävä hyvinvointi, Valtioneuvoston kanslian raporttisarja 12/2011.

Weitzman, M.L. (1976), "On the Welfare Significance of National Product in a Dynamic Economy", *The Quarterly Journal of Economics*, 90: 156–162.