Inflation in the Digital Age: Inflation Measurement and Bias in the 21st Century*

György Matolcsy – Márton Nagy – Dániel Palotai – Barnabás Virág

In a highly timely move, several major central banks have announced a thorough review of their inflation targeting systems in recent months. Official statistics show that consumer inflation in the developed world has remained consistently below central banks' target rates for almost a decade, in spite of the extraordinary efforts of these central banks. If central banks miss targets permanently, they may incur credibility problems and, over time, this could erode the social acceptance of their decisions. The world and our economies in it are undergoing an extraordinary transformation. 21st century megatrends such as digitalisation, the transformation of globalisation, ageing societies or even climate change are introducing new patterns into how economies function. Closely related to these megatrends, phenomena such as changing consumer habits and an increased importance of services pose new challenges for the measurement of economic processes, including the rate of inflation. One first step in the reconsideration of inflation targeting frameworks can be to correctly identify new types of bias in the measurement of inflation and to understand the new patterns determining the changes in consumer prices. Besides its challenges, technological progress offers new solutions as well. The widespread adoption of big data technologies has also created a significant opportunity for enhancing economic statistics; benefiting from these advantages, economic theory can help economic policymakers again, providing them with more solid support than over the past decade.

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1. Motivation and introduction

In a highly timely move, several major central banks have announced a thorough review of their inflation targeting systems in recent months. Official statistics show that consumer inflation in the developed world has remained consistently below central banks' target rates, in spite of the extraordinary efforts of these central banks. If central banks miss targets permanently, they may incur credibility problems and, over time, this could erode the social acceptance of their decisions.

The world and our economies in it are undergoing an extraordinary transformation. Technologies, new monetary systems, mobility, data revolution and climate change are just a few of the new challenges of the 21st century. Robotics, big data and artificial intelligence are reshaping an ever greater slice of our lives and the global map is undergoing fundamental geopolitical changes. Closely related to these megatrends, phenomena such as changing consumer habits and an increased importance of services pose new challenges for the measurement of economic processes, including the rate of inflation. One first step in the reconsideration of inflation targeting frameworks is to correctly identify new types of bias in the measurement of inflation and to understand the new patterns determining the changes in consumer prices. Besides its challenges, technological progress offers new solutions as well. The widespread adoption of big data technologies has also created a significant opportunity for the enhancement of economic statistics; benefiting from these advantages, economic theories can help economic policymakers again, providing them with more solid support than over the past decade.

This paper examines inflation in the 21st century, i.e. the digital age; it seeks an answer to the question whether inflation, as it is currently known, provides an accurate understanding of the 'true' changes in prices, taking into account the impact of megatrends. The paper is structured as follows: *Chapter 2* presents the theories most frequently used in the past fifty years to explain inflation. *Chapter 3* examines the factors that are currently less suitable for describing inflation trends, while *Chapter 4* presents the new factors having an increasing effect on inflation. *Chapter 5* deals with inflation measurement and biases. Finally, *Chapter 6* summarises the main conclusions.

2. Theories to explain inflation

From time to time, economists and economic policy makers would monitor different factors underlying the understanding of the given period regarding the development of prices. In the pre-crisis period, the two pillars of inflation thought and theory were the quantity theory of money and the Phillips curve.

2.1. The quantity theory of money

For traditional correlations, we have to go back as far as the 1960s, when Nobel laureate economist Milton Friedman developed the new foundations for monetarism and the quantity theory of money. Different versions of the quantity theory of money date back as far as the 16th century, when the precious metal flows from the Americas to Europe gave rise to the observation of a linear relationship between the quantity of money and the level of prices. Among others, the philosophers John Locke and David Hume and the economist Richard Cantillon tackled the subject.

The earliest version of the quantity theory of money was developed by Irving Fisher. His assumption was that market participants held money for transaction motives only, and that the velocity of money was exogenous. John Maynard Keynes was highly critical of this approach, pointing out that, in addition to the transaction motive, market participants may also hold cash for precautionary or speculative motives. Market participants have a precautionary demand for money to prepare for unexpected future expenditures; this is dependent on their expected future incomes. With the speculative motive, wealth can be held in cash or in bonds. Bonds are recommended in this case because, unlike cash, they also have a yield. These two motives introduce the role of the interest rate into the theory: the velocity of money changes as a (positive) factor of the interest rate.

The Keynesian approach is an improvement on Fisher's assumptions because it uses more motives to explain why market participants hold money and declares the velocity of money to be dependent on the interest rate. However, the speculative motive is unable by itself to justify the need for diversifying asset portfolios by dividing them between cash and bonds.

Modern monetary policy emerged after the collapse of the Bretton Woods system in 1971. A deeper understanding of inflation became the focus for economic research with the monetary revolution led by Milton Friedman who, in his book published in 1963[1], presented a reformulated quantity theory of money using the example of the US economy; in this theory, the nominal money supply determines the rate of inflation:

$$M \cdot V = P \cdot Y,$$

where M is the nominal money supply, V is the velocity of money, P is the price level and Y is the real output of the economy. In contrast to the Keynesian approach, one of the assumptions in the theory is that the velocity of money is constant, i.e. the money available in the economy is spent by market participants

[1] Friedman, M. – Jacobson Schwartz, A. (1963): *Monetary History of the United States 1867–1960*. Princeton University Press, Princeton, 1963.

on goods and services at similar degrees in all periods. Another assumption is that the additional demand resulting from the additional quantity of money in the economy must always meet with adequate supply. Friedman warned, however, of increasing the quantity of money too quickly. In an optimal scenario, therefore, increasing the quantity of money will first lead to increased demand and economic growth (short-term impact), and will then have inflationary consequences in the longer term. In contrast to Keynes' theory, Friedman did not consider it necessary in his monetarist approach to separate the speculative and the transaction motives, nor did that approach attribute a significant role to the impact of interest rates. Although Keynes and Friedman never debated their theories in person, a comparison of their theories can reveal how stark the contrast was between them.

2.2. The Phillips curve

In addition to the quantity theory of money, the consensus before the 2008 crisis sought to capture price changes using an economic relationship first discovered in the 1950s. The Phillips curve correlation was developed on monetarist foundations and tied the changes in inflation to the cyclical positions observed in the economies. In his article published in 1958, Phillips tested the relationship between unemployment and wages (wage inflation) on data from the United Kingdom, and found a stable inverse relationship, which became a milestone in the development of macroeconomics (*Phillips 1958*).

The original correlation needed fine-tuning from time to time, however: in the 1960s, Solow and Samuelson replaced the changes in wages with changes in prices; in the mid-1970s, inflation expectations were added; and in the 1990s the theory was given its microeconomic foundations based on Neo-Keynesian logic (*Szentmihályi – Világi 2015*).

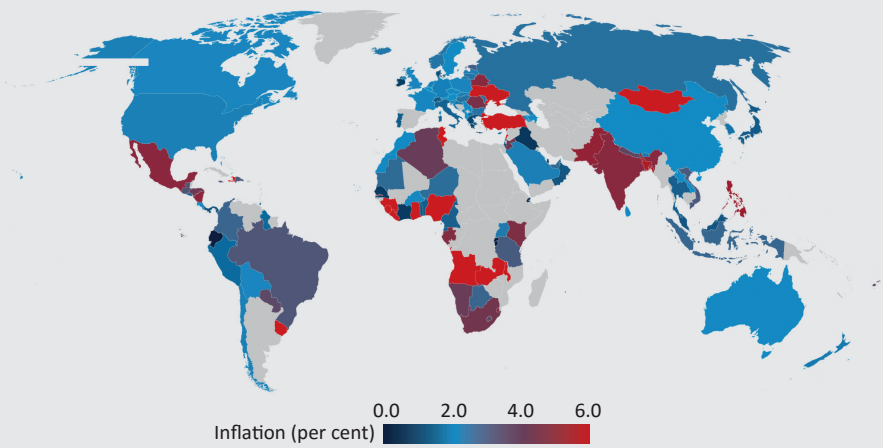
The role of cyclical factors in determining inflation (i.e. the slope of the Phillips curve) was an important component of the so-called 'divine coincidence' principle (*Blanchard – Galí 2005*), according to which stabilising inflation results in stability in the real economy. Also, according to the economic thought of the time, inflation expectations served the purpose of capturing changes in inflation in the longer term, beyond the real economic cycle. Central banks declared inflation targets in order to anchor expectations at the desired level and, in addition, used the standard tools of central bank interest rate policy to smooth the fluctuation of inflation and real economic indicators.

2.3. What is happening to inflation nowadays?

There have been several periods in the history of inflation over the past fifty years or so when global inflation rates were relatively high in advanced as well as emerging economies. This was due mostly to a substantive rise in commodity prices, primarily crude oil, as a result of geopolitical reasons. The gradual introduction of inflation

targeting, first in New Zealand, in January 1990, contributed to the fact that global inflation rates stabilised at a moderate level near the declared inflation targets in the period from the mid-1990s until the crisis of 2008.[2] Nowadays, however, developed countries live in an age of low inflation, with rates below central banks' targets. As Federal Reserve Chair Jerome Powell said at a FOMC press conference in March 2019, globally low inflation is 'one of the major challenges of our time' (*Figure 1*).

Figure 1
Consumer inflation in the world in 2018



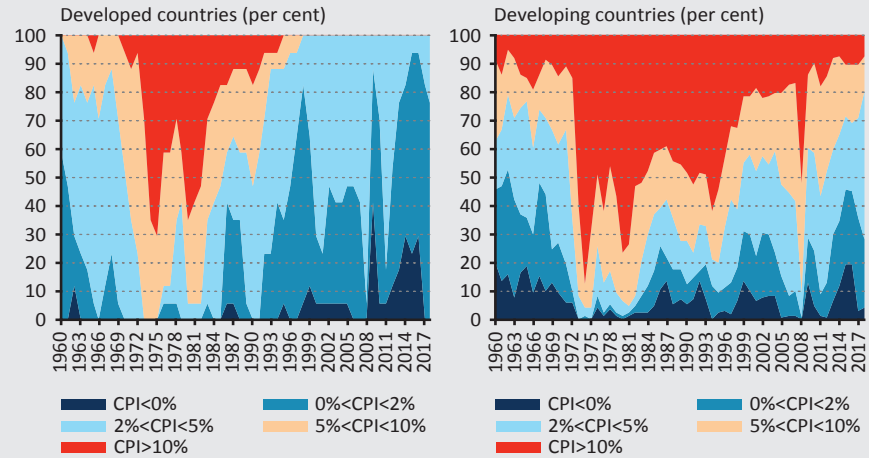
Note: Annual change. Minimum: –2.8 per cent, maximum: 23.6 per cent. Data is not available for the countries shown in grey.

Source: World Bank

Although favourable global economic processes and a mild increase in commodity prices pushed inflation rates out of their former range around 0 per cent, inflation still remained below central banks' targets (*Figure 2*). The percentage of advanced countries with a rate of inflation between 0 and 2 per cent has risen to nearly 80 per cent since 2012. The trend is similar in emerging countries, which makes the problem of low inflation a global phenomenon. Where has inflation gone and how do we explain the way prices are changing nowadays? Below we seek answers to these questions.

[2] The process is clearly illustrated by the diagrams in the Annex. While many countries in the world were characterised by high inflation in 1990, falling inflation rates were observed in an increasing number of economies by 2000.

Figure 2
Distribution of inflation rates in developed (left panel) and developing (right panel) countries (1960–2018)



Note: Ratio of specific categories of countries within given groups of countries.
Source: World Bank, The Economist[3]

3. Changed relationships

Factors that used to provide an important compass for our understanding of inflation processes have been significantly weakened in the current global economic environment of low inflation. To fix our broken compass, we need to understand where the traditional economic models are broken.

3.1. The shrinking importance of the quantity theory of money

Doubts about the practical application of the quantity theory of money were first raised in the 1980s and 1990s, and it has lost much of its relevance since then. This is partly attributable to the fact that the velocity of money is not actually constant. The M1 nominal money supply is not an appropriate measure of liquidity as it does not capture loans and it disregards alternative forms of savings such as equities and government securities.

When the stock markets perform well, market participants choose to buy shares to achieve higher yields, which reduces the velocity of money. If people enjoy a substantive improvement in their wealth due to higher yields from equities, they will increase demand in the economy and this in turn will raise output. In such situations, asset price bubbles can easily emerge and pose a risk to the economy as a whole.

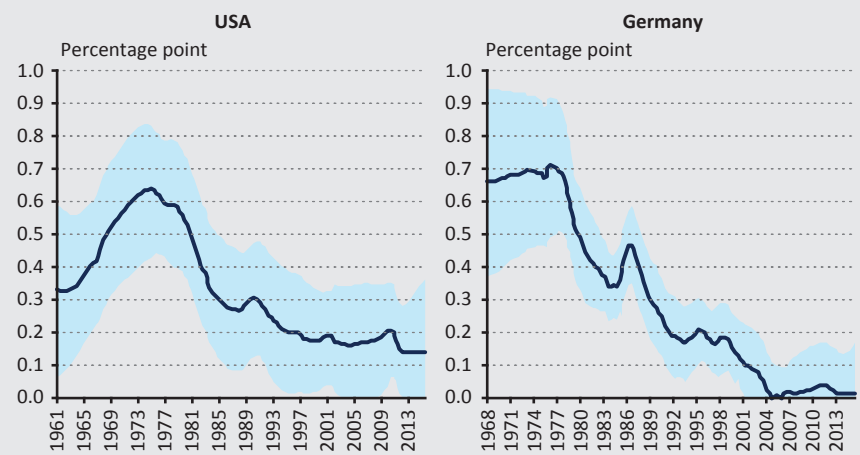
[3] The Economist: *Special Report: The end of inflation?* 10 October 2019, Vol. 433 (9164)

Later, Friedman himself questioned the functioning of the quantity theory of money, telling the *Financial Times* in June 2003 that: *'The use of quantity of money as a target has not been a success. I'm not sure I would as of today push it as hard as I once did.'*[4]

3.2. The Phillips curve is mostly flat today

Since the economic crisis, the Phillips curve has performed badly in the school of economic life: the high unemployment prevailing overall should have had a significant disinflationary impact, but this did not happen in the advanced countries. In the period of 'missing disinflation', the *IMF* (*2013*) called the Phillips curve 'the dog that didn't bark'. Today, the central banks of the world are increasingly faced with the problem of 'missing inflation'. To understand this phenomenon better, *Blanchard et al.* (*2015*) conducted a comprehensive study and estimated the slope of the Phillips curve over time in the United States and Germany (*Figure 3*). Whereas in the mid-1970s a change in the unemployment rate by one percentage point would (with a given 'equilibrium' unemployment rate) alter the rate of inflation to approximately the same degree, that impact shrank to 0.1 percentage point by the 2010s. A similar pattern can be observed in other advanced countries as well; this is referred to in literature as 'the flattening of the Phillips curve'.

Figure 3
Changes in the slope of the Phillips curve in the United States (left panel) and Germany (right panel)



Note: Changes in the unemployment gap coefficient over time. The band denotes the one-standard deviation distance from the estimated coefficient value.

Source: Blanchard et al. (*2015*)

[4] London, S. (2003): *Lunch with the FT: Milton Friedman.* Financial Times, 7 July 2003

What could be behind the flattening of the curve? The most widely offered explanation is globalisation, since it is estimated that the role of global factors in determining the rate of inflation has intensified since the crisis (*Ciccarelli – Mojon 2010; Forbes 2019*). *Nagy – Tengely* (*2018*) arrived at the same conclusion using data from Hungary. This trend may fundamentally alter everything we have thought about inflation in the last 20 to 30 years and highlights the need for identifying new correlations if we are to understand inflation processes better.

Another approach to the Phillips curve is to analyse the relationship between prices and wages. Since the crisis, the strength of the link between wages and inflation may have changed in advanced countries, including the Member States of the EU (*Nickel et al. 2019*). The changes in wages have an impact on inflation via household demand, corporate costs and inflation expectations. Inflation expectations since the crisis have been anchored at low levels. If inflation expectations are lower, employees have less of an incentive to push for higher nominal wages at wage negotiations as they expect lower inflation, which contributes to a change in the relationship between wages and inflation. Corporate costs are dependent on the corporate tax rates, the cost environment and gross wages. In Hungary, corporate wage costs have risen less than gross wages because of the cut in taxes on labour. Household demand is shaped primarily by income trends: rising wages increase the available income of households, and when such extra income is spent, consumption rises along with demand-side inflation. It is worth taking into consideration at what average and marginal savings rates wages will rise, i.e. what additional demand will appear on the market of consumer products.

3.3. Exchange rate pass-through in open economies is now moderate

The question of exchange rate changes and pass-through is an important one in open economies. The changes in exchange rate can influence inflation through various channels: directly through the rising prices of imported goods and indirectly through the impact on expectations and the business cycle. The consensus in literature is that the impact of the exchange rate on prices decreases along the progress in the production chain and there is only limited pass-through to consumer prices (*An – Wang 2011*).

Since the crisis, the relationship between exchange rate and inflation has changed mainly in the emerging countries (*Forbes et al. 2017*). *Hajnal et al.* (*2015*) divided the reasons underlying the changed nature of exchange rate pass-through into cyclical and structural factors. They found that, as a result of the significant fall in aggregate demand during the crisis, companies were less able to pass exchange rate changes through into their prices. The relationship was also influenced by the decrease in inflation rates in general and the fact that expectations became more anchored. In addition, market participants respond less to a volatile exchange rate

because they may consider rate movements to be temporary. Finally, another significant factor for exchange rate pass-through is what part of the consumer basket is subject to government regulation: the greater that part is, the lower the impact of the exchange rate channel will be.

3.4. Where is the Balassa–Samuelson effect?

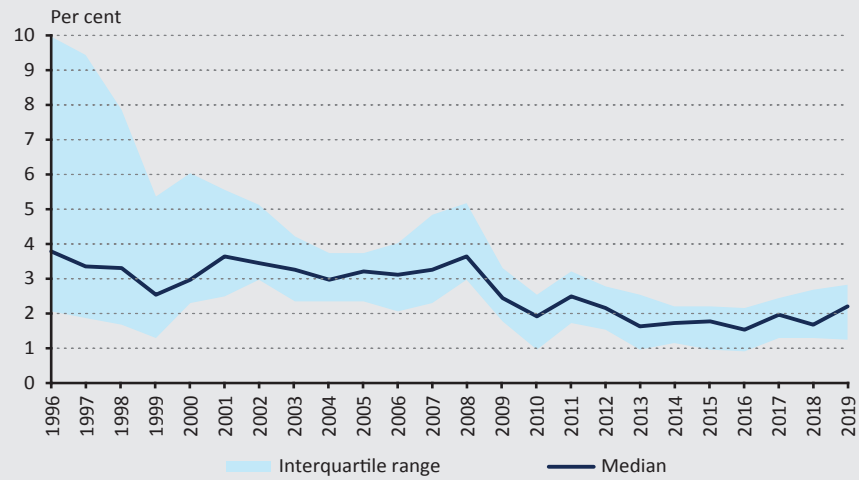
A traditional correlation well known in international economics is the close correlation between the development of an economy and the level of prices. The Balassa–Samuelson effect — a correlation with Hungarian relevance developed in the 1960s — states that the convergence of price levels is achieved through higher inflation in services.

For the theory to apply, the sector of tradable goods must be separated from the sector of non-tradable services. The assumptions are that it is less feasible to increase productivity in the services sector (the productivity of a haircut or dental treatment will be the same everywhere), labour cannot move freely across countries and trade is free. If all these apply, then prices will be lower in the more productive manufacturing sector and higher in the less productive services sector.

Does the Balassa–Samuelson effect still apply in today's highly accelerated and globalised world? The changes taking place in recent decades suggest that these assumptions formulated half a century ago are unlikely to be applicable still and that the current wave of innovation in technology is reshaping the productivity of the services sector. As a result of globalisation, trade among countries is free not only in theory but also in practice. The free movement of labour is almost obvious nowadays.

Contradicting the theory, the global rate of inflation in services has been falling for more than two decades (*Figure 4*). This highlights the fact that the role of services has changed as a result of globalisation, digital technological development and the transformation of the trading of services, and that the resulting inflation effects must be seen from a different viewpoint.

Figure 4
Development of global inflation in services



Note: Based on data from 31 OECD countries
Source: MNB calculations based on OECD data

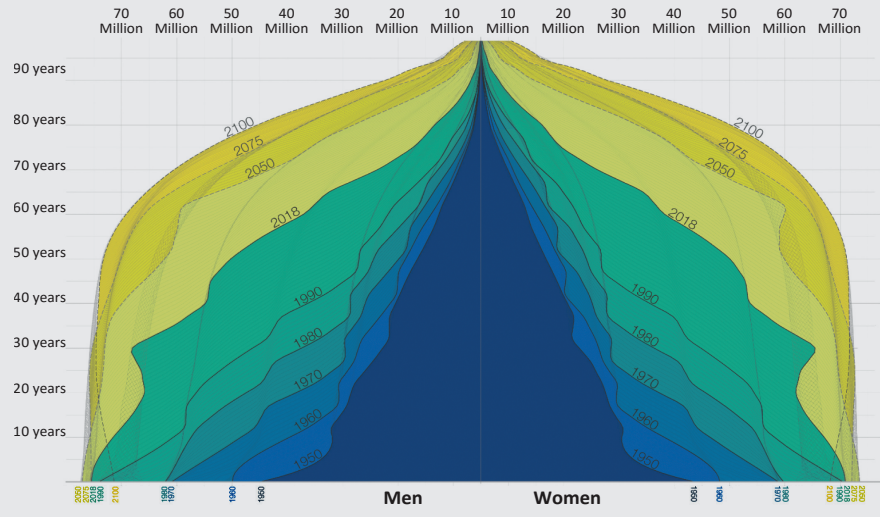
4. Five new megatrends with an increasing impact on inflation

The inflation theories of the past 50 years (the quantity theory of money, the Phillips curve, exchange rate pass-through, the Balassa–Samuelson effect) are unable to explain the current processes well, which means that we are witnessing a paradigm shift in respect of the determinant factors of inflation. We must focus our attention on the new trends of the post-crisis period, namely digitalisation and technology, demographics, globalisation and climate change.

4.1. Demographics

Examining the inflation impact of demographic trends is a priority in today's literature as well; after all, with the rise in life expectancy in most advanced countries, the age composition of the population is undergoing a substantive transformation (*Figure 5*). The proportion of young and old people is rising the number of working-age people is decreasing, which can have an effect on inflation as much as the real economy. A clear consensus is still lacking, although the view has started to prevail that demographic processes have a significant impact on today's environment of globally low inflation and that this disinflationary effect will continue into the future. It is especially hard to answer this question due to the fact that demographic transformations tend to exert their influence over decades rather than the time horizon of a business cycle.

Figure 5
Changes in world population age structure (1950–2100)



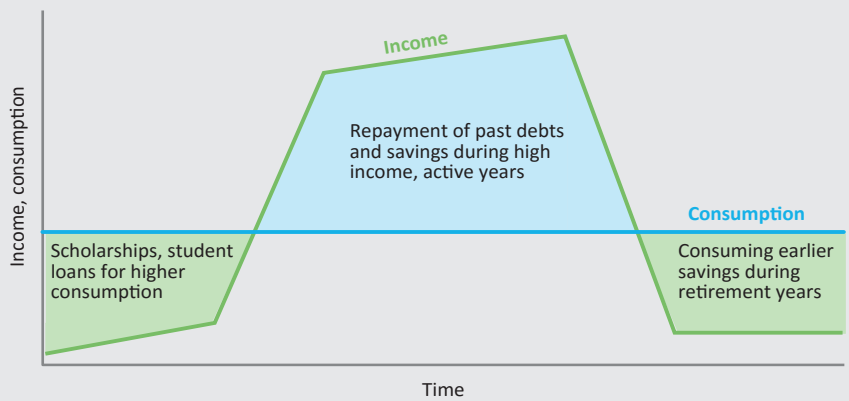
Source: OurWorldInData.org

Demographic processes are shaped by three trends overall: firstly, while the world population is continually rising, advanced countries are faced with a decrease in their populations in the longer term. Secondly, as the proportion of the elderly rises, the number of working-age people decreases within the population. And finally, a further increase in life expectancy is expected in most advanced countries as healthcare provision and living standards improve.

The three main demographic trends have contradictory effects on inflation. The change in age composition and higher life expectancy have contributed to an environment of more moderate inflation in recent decades. *Yoon et al.* (*2014*), *Anderson et al.* (*2014*), *Vlandas* (*2016*) and *Bobeica et al.* (*2017*) attribute the negative inflation impact of an aging society to the behaviour of the elderly age group, whose consumption and savings habits and inflation expectations are different from those held by the active population. The elderly also need different fiscal policy behaviours (transfers to the elderly, regulated prices, etc.). And while the proportion of seniors was already rising back in 1970, the inflationary effects were offset then by the high proportion of working-age people and the increase in life expectancy. This may be reversed in the next few decades as the decrease of the working-age population accelerates.

An aging population may contribute positively to inflation. Research by *Lindh – Malmberg* (*1998, 2000*), *Goodhart – Pradhan* (*2017*) *and Aksoy et al.* (*2015*) suggests that this is due to the fact that as the number of active persons decreases, employees have a better bargaining position at wage negotiations, which results in higher wages and this, in turn, contributes to the rise in available income and internal demand. An inflationary impact also follows from the life-cycle hypothesis proposed by *Ando – Modigliani* (*1963*). According to this hypothesis, young individuals have a lower income, which rises continually during their active years up to a certain point, and then decreases after retirement. This would imply that the elderly and the young consume less than the working-age population, whereas most people tend to smooth their consumption over their lives (*Figure 6*). When young individuals can increase their consumption to the desired level by relying on various scholarships and student loans. In their active period, even as their higher income would justify more consumption, it makes sense for them to curb their consumption and repay their old loans or increase their savings. During the years of retirement, income once more falls below the desired consumption level, but this can be offset with savings previously accumulated. *Ceteris paribus*, inflation impacts will intensify in the countries where the group of net savers (active people) is limited, because the dominant effect is that of the larger group, that of net consumers (young and elderly people), driving up inflation.

Figure 6
A stylised diagram of the Ando–Modigliani life-cycle model



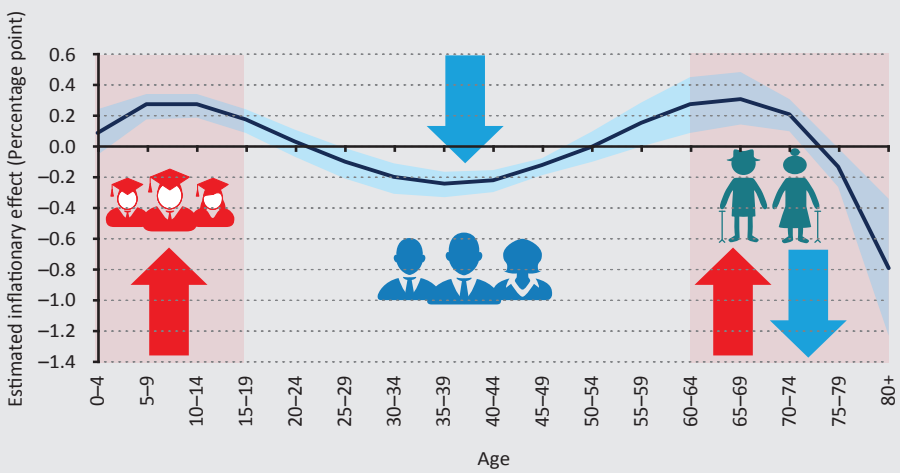
Source: Wolla (*2014*)

This is not always coupled with an environment of permanently higher inflation in the advanced countries: if the inflationary effect of an aging population is offset by the decrease in demand due to a shrinking population and the increase in non-labour-intensive supply thanks to robotisation, a lower inflationary impact may

be expected in the longer term. This is confirmed by *Juselius – Takáts* (*2018*) in their analysis of 22 advanced countries, according to which there is a U-shaped relationship between the age composition of the population and inflation (*Figure 7*), in agreement with the life-cycle hypothesis. In the case of the over 65s though, the inflationary impact is mixed, and there is greater uncertainty regarding estimated outcomes.

The aging of a population changes the composition of the median consumer basket. Foods and services, especially healthcare services, represent a greater weight within the consumer basket of the older age groups. In the case of healthcare services, the inflationary impact depends on whether the given representative consumer prefers public or private healthcare services: prices are regulated in the former, whereas prices in the latter are determined by demand.

Figure 7
The estimated inflationary impacts of different age groups



Note: The light blue band denotes the +/– 2 standard deviation distance from the estimated coefficient value.
Source: Juselius – Takáts (*2018*)

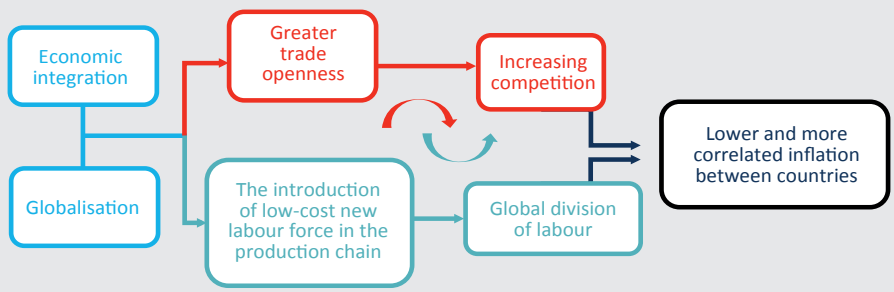
4.2. Globalisation

The weakened ability of traditional hypotheses to explain inflation processes has left economists with a puzzle they are still trying to solve in order to get a more precise and consistent understanding of the processes taking place in the economy. One important element is globalisation, which means the cross-border movement of goods, services, money and production factors, which binds economies together with ever closer ties.

Globalisation has also brought inflation rates closer together all over the world. This process was accelerated by the inflation targeting regimes first introduced in the 1990s. Prices were no longer determined by the situation on the local market but by an international environment expanded with the rise of global value chains.

Guerrieri et al. (*2010*) believe that globalisation and economic integration can affect inflation processes in multiple ways, so that greater trade openness, intensifying competition, a global division of labour and the low-cost new labour appearing in the production chains all contribute to a lower price dynamic and a greater synchronisation of inflation rates (*Figure 8*).

Figure 8
The inflationary impact channels of globalisation



Source: Edited by MNB

The integration of product markets causes inflation to respond to internal capacity constraints less sensitively: a sudden increase in demand can drive imports up without resulting in higher prices. Globalisation exerts an influence on inflation through international trade as well; this is closely associated with the rise in the importance of global value chains. According to the global value chain theory, global production processes — which are increasingly dispersed geographically — have enabled the spread of new technologies and reduced trade barriers. In economies that are more open, price and wage dynamics are much more sensitive to the effects of the external environment and, at the same time, inflation's sensitivity to internal factors is increasingly small (*Forbes 2019; Nagy – Tengely 2018*).

Going forward, globalisation may have a substantive impact on inflation. Yet the globalisation process is undergoing a change at the moment: the further expansion of the global value chains built in the early 2000s appears to be slowing; in fact, the process may have reversed already. This is due to the efforts made in emerging countries such as China to develop local value chains, either within their own borders or together with their neighbouring countries, in order to reduce their dependency on global trade (*McKinsey 2019*). In addition, the global world is keeping an eye on

the trade war between the USA and China. In that light, it will be worth monitoring the process of borderless price developments in the (near) future too.

4.3. Digitalisation and technological progress

The progress of digitalisation and the spread of robot technologies is one of the most important megatrends of the 21st century, with a number of impacts on society and the economy. One of the most important questions for central banks is to what extent the technological revolution can explain the current, globally moderate inflation processes.

Today's digitalisation technologies—mobile technology, big data analyses, cloud computing, sensors, digital platforms and automation—may significantly change the way companies have traditionally operated and how they work with their suppliers and serve their consumers. The question is what pricing strategies companies will follow in an environment of fast-evolving technologies and how the digital transformation will affect the related supply chains. Although the quantitative results are still uncertain and difficult to isolate from other factors (for instance globalisation), a survey of Canadian corporates on the subject shows that the disinflationary effects of digitalisation may also stem from decreasing costs and downward competitive pressure on prices (*Dong et al. 2017*).

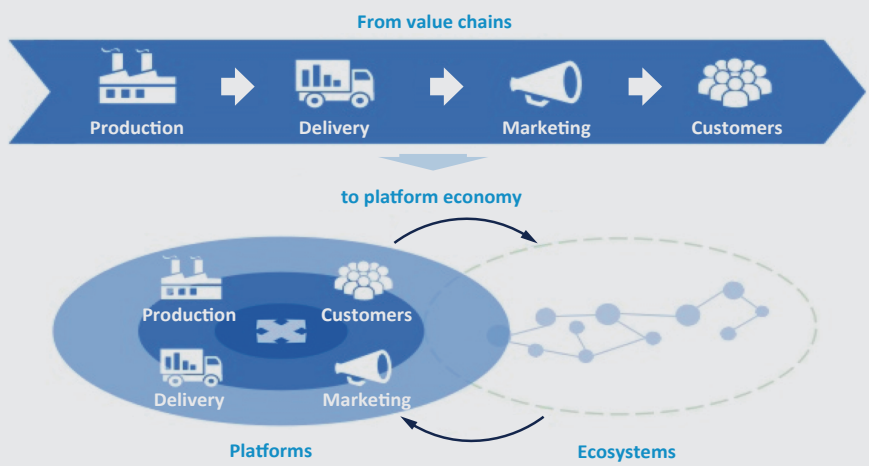
Traditional corporate operations are facing a revolutionary change in a process taking place right before our eyes, which is best encapsulated in the expression 'the middleman is dead'. New digital technologies are completely transforming the traditional value chains from producers through wholesalers and retailers to consumers, and the so-called platform economy is redefining this operational process (*Lyall et al. 2018*).

The platform economy was created by the dramatic recent rise in the role of the internet. Besides the radical changes it has brought to our daily lives, the online world has also transformed the way some markets operate. Whereas the first industrial revolution centred on factories, the drivers behind the changes today are digital platforms in the wider sense of the word. Relying on the internet and online platforms, the platform economy is an umbrella term covering the digital companies operating online and performing a variety of commercial, social and other activities (*Kenney – Zysman 2016; OECD 2019a; MNB 2019*). There is no single universal definition of digital platforms. Following litereture, based on the terms used by the European Commission or the OECD, we can summarise their main features as follows:

1. they use information and communication technologies to create interaction between users,
2. they collect and use the data of these interactions, and
3. they exploit the network effects.

Online platforms are becoming an engine of innovation. Operating on internet-based platforms there are various on-line marketplaces (Amazon, Alibaba), search engines (Google), social media networks (Facebook), communication services (WhatsApp), payment solutions (Revolut), music and video sharing portals (Spotify, YouTube) and many others, which would have been unimaginable just a few years or a decade ago. In the platform economy, the conventional relationship between market players has changed; a pattern of everyone connected to everyone is much more typical. Ecosystems also play an important role; typically, these play a sort of supporting role rather than being controlled by the platform operator. *Figure 9* presents the operational principle of the platform economy.

Figure 9
The operational principle of the platform economy, or 'the intermediary is dead'



Source: Grow VC Group

The advantage of the platform economy is in its speed: to create fast, change fast and innovate fast. All this is closely related to creative destruction, where a platform company has the ability to cause dramatic change on existing markets or to create entirely new ones. One example is that of the US-based Blockbuster video rental chain, which was established in the 1990s and grew into a genuine international company by 2004 but went bankrupt in 2010 as a result of the emergence and spread of Netflix. Change is continual as new sales platforms and channels are being created and result in intensified competition which has downward pressure on consumer prices.

The pricing and economic effects of the platforms are closely connected to digitalisation, which is an important and dominant trend today. The internet and digitalisation exert their effects on inflation via four main channels (*Figure 10*), which are:

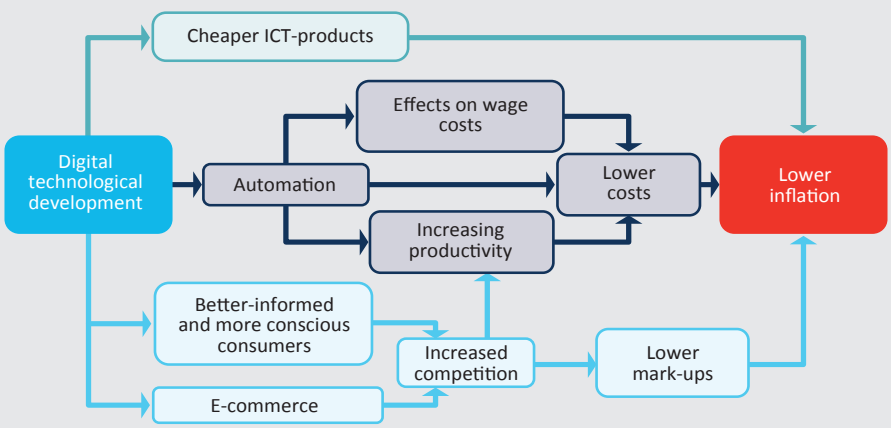
1. e-commerce,

2. more conscious and better-informed consumers,

3. automation, and

4. the development of IT (ICT devices).

Figure 10
The main inflation channels of the internet and digitalisation

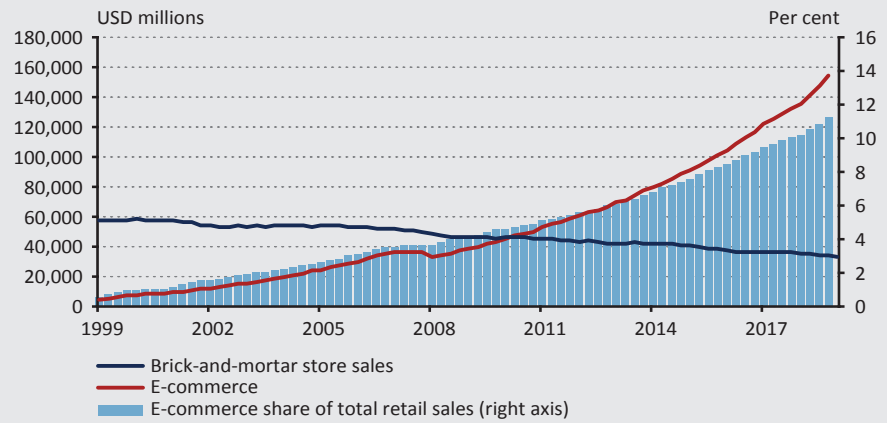


Source: Riksbank (2015)

E-commerce, which would be hard to separate from globalisation, can reduce prices fundamentally by increasing the competition among companies and changing the traditional business model. Online selling can reduce the costs (wage and rental costs) incurred in retail and wholesale trade. Low marginal costs then contribute to the reduction in the prices of goods and services.

In the US economy, e-commerce sales are growing exponentially, while store sales have been falling since the crisis (*Figure 11*). E-commerce may soon find a challenger in m-commerce (mobile commerce), as sales move from computers to mobile telephone screens and into a variety of apps.

Figure 11
Store and online sales in the USA



Note: Seasonally adjusted data until 2019 Q3; for commodity sales, until the end of 2019.
Source: Federal Reserve Bank of St. Louis, US Commerce Dept.

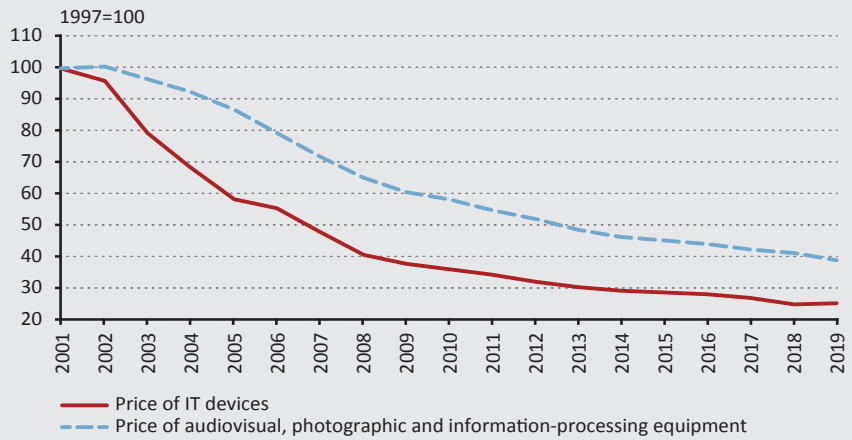
Increased consumer awareness has been an impact of e-commerce that is difficult to measure. With internet usage growing, consumers are increasingly aware and better informed, which drives competition on price. Consider how we almost all have a smartphone in our pockets or a smartwatch on our wrists, giving us instant access to all the information we need at any given moment. Since we can compare the prices of the products and services we want with a single click, companies must be on the alert if they want to attract potential customers; they compete against other sellers by offering ever lower prices and various discounts.

Automation, robotisation, the increased complexity of production processes and the spread of artificial intelligence are changing how companies operate and transforming the production chains. As a result, efficiency and labour productivity are rising on the supply side, and the reduction of the marginal costs of production may both increase profits and be reflected in consumer prices. On the demand side, automation is causing a polarisation of incomes. However, the increase in the proportion of high-income groups is not resulting in a substantive rise of consumption because these households tend to put their additional income into savings; it is therefore less clear whether there is an inflationary impact on the demand side.

The fall in the prices of information and communication technology (ICT) products and services over recent decade(s) has reduced inflation directly. There may be additional second-round effects such as, for example, the incorporation of products

with increasing digital technology content into production processes (Industry 4.0), which increases productivity and reduces costs. The products most affected by digitalisation are information technology devices and audiovisual, photography and information processing equipment. The most significant fall in prices over the last two decades has been in information technology devices (*Figure 12*).

Figure 12
Changes in the prices of products most affected by digitalisation in Hungary



Source: Eurostat, MNB

4.4. Climate change

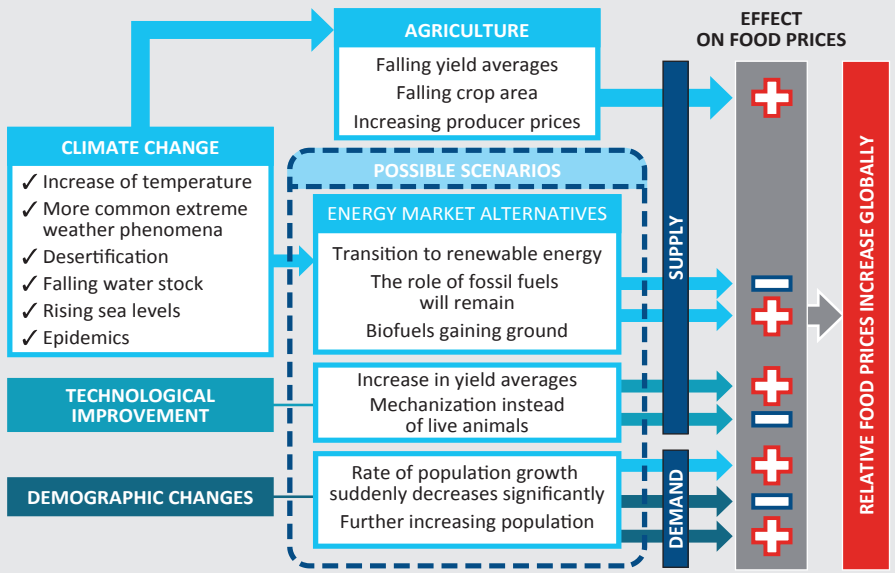
The climate change phenomenon is unavoidable when analysing global trends. Although an increasing number of studies are examining the economic impacts of climate change, there is genuine uncertainty surrounding the estimates. The pace of global warning, the ability of technological progress to adapt or the impact of climate change on global activity are difficult to model or measure with precision.

In his talk on "Monetary policy and climate change", ECB Executive Board member Benoît *Cœuré* (*2018*) pointed out that central banks should be ready for regular and even persistent supply shocks. He emphasised that the changes in relative prices were highly dependent on the extent to which the economy shifted from carbon-based energy production to renewable sources of energy. He called it a responsibility of central banks to make sure that they are prepared for the various scenarios and that they anchor the inflation expectations correctly.

Increasingly frequent extreme weather phenomena, rising temperatures or desertification caused by climate change affect agricultural output directly, resulting

in lower average yields, a smaller total cultivated area and rising production prices (*Figure 13*). In addition to the climatic changes, technological progress and demographic changes must also be taken into account, as they too have an impact on food prices. A rising population will also need access to freshwater supplies and the use of free lands. Climate change will limit the availability of both of these resources, driving up the prices of foods.

Figure 13
The expected impact of climate change and the related possible scenarios on the relative prices of foods



Source: Edited by MNB

Automotive industry trends also have a substantial impact on food prices due to the spread of biofuels. If these were to be used increasingly widely, food prices could rise permanently. Planting land with 'energy crops' used as raw material for biofuel, such as sugar beet or sugar cane, would take land away from the cultivation of food crops.

The food industry is highly oil- and energy-intensive, and this is likely to intensify with the mechanisation under way in the developing countries. Globalisation increases the distance between the production and consumption of food, and the fuel demand of transportation is also high. In food sales, large quantities of energy are used for packaging and storage (cooling, freezing). As a result of all of the

above, the changes of relative prices will be highly dependent on energy market processes.

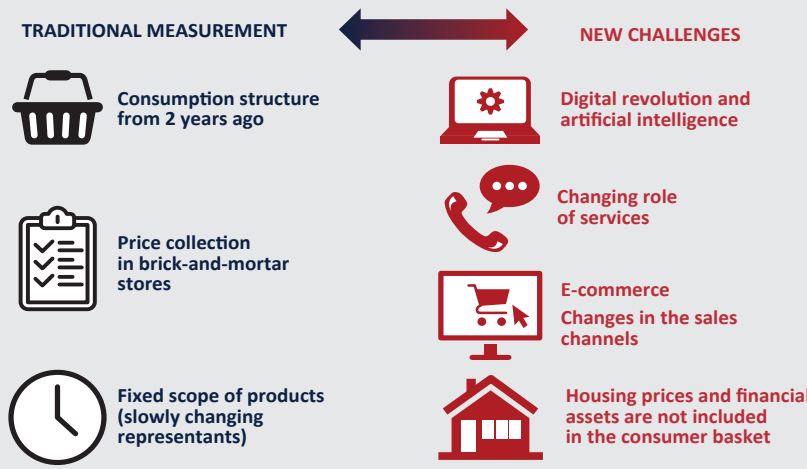
The overall effects of climate change increase relative food prices globally and thus contribute to rising rates of inflation. The climate change phenomenon is not new, but its earlier inflationary impacts were mitigated by the fact that large corporations in advanced countries outsourced much of their production process—and thus the associated polluting activities—to developing countries such as China or India, where costs were cheaper. The process was greatly accelerated when China became member of the WTO in 2001. Today we are witnessing a turning point; as the climate change affects emerging countries most, they have adopted measures in the interest of sustainability. As a first step, China regulated the quality of reusable plastics in 2013 and declared that it would only accept cleaned waste from other countries. In 2018, China introduced import limits on 24 types of reusable waste as part of its overall environmental reform, thus ending a process that had lasted for a quarter of a century.

5. Inflation measurement biases in the 21st century

Inflation is one of the most important and most monitored macroeconomic indicators for central banks. When speaking of inflation, we normally refer to the changes in consumer prices. The purpose of the consumer price index is traditionally twofold: it serves as a compass for monetary policy and also plays an important role as an index of the cost of living.

This methodology, which is still used in Hungary today and was developed in the early 1970s to measure consumer price change, is facing new challenges in the 21st century. Complemented with big data, the digital revolution and artificial intelligence are making unprecedented quantities of data available, which can provide a much more accurate picture of the development of prices. The economic role of services is also changing, and besides, e-commerce is gaining ground in the platform economy, while the changing sales channels are exerting impacts that differ from the customary impacts of the past. The task is therefore to bring traditional statistics closer to the trends of the 21st century (*Figure 14*).

Figure 14
New challenges of the 21st century versus traditional measurement



Source: Edited by MNB

According to the latest knowledge and general statistical practice, inflation is a relatively accurate and high quality indicator for the measurement of price change. We must remember, however, that its relative accuracy implies it actually has (many) shortcomings. Attention was drawn to these shortcomings and inaccuracies already in the 1990s, for instance in the report of the *Boskin Commission* (*1996*), which named the following four most frequent biases in measurement:

1) substitution between products,

2) changes in sales outlets,

3) emergence of new products,

4) changes in quality.

Nowadays a new technological revolution is happening right before our eyes. Ever more products and services are emerging thanks to digitalisation, while the opportunities available to consumers are also widening; moreover, the consequences are hard to quantify. As Raymund *Kurzweil* (*2001*), an internationally recognised expert on the subject said: '*We won't experience 100 years of progress in the 21st century—it will be more like 20,000 years of progress'.*

This process has already started and exerts a significant impact on consumer prices as well as multiple areas of the measurement of economic progress. The computing capacity of our machines is growing exponentially, an ever larger slice of our economic transactions and social interactions is shifting to cyberspace, value no longer means the possession of physical objects but experiences or perhaps access to a variety of platforms instead, and, with increasing frequency, we are paying for these with information rather than money. Accordingly, we can add the following 6 items to the above list, based on the results of research published and the technological changes since then:

1) emergence of digital products;

2) traditional sales and online platforms;

3) statistics not properly reflecting the life-cycle of products;

4) 'pricing' of free content;

5) 'bundling';

6) omitted products and services.

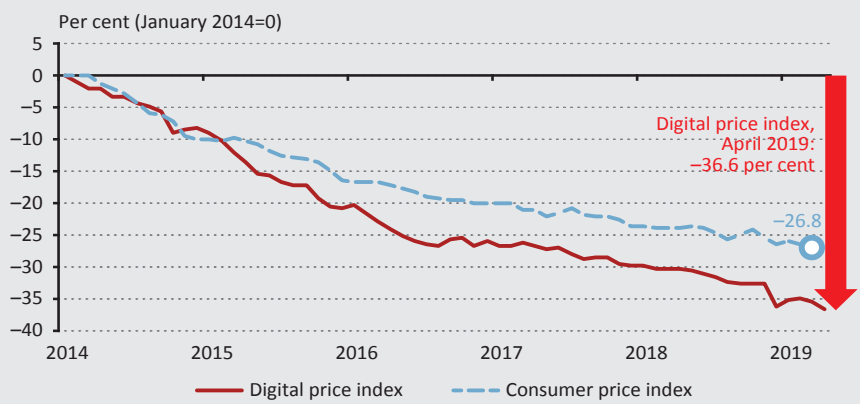
Substitution among products means consumers responding to product price changes on the basis of how their relative prices have changed. Yet the composition of the consumer basket will reflect this change only with a delay.

The change in sales outlets, in the traditional sense, means consumers start to shop in new stores, finding lower prices and a wider choice in a supermarket than in a small shop. However, 'cheapness' is not the only possible reason for such a switch: if they want to buy healthier or higher-quality foods, they will start going to organic food stores, where prices may be higher but they will feel better in the knowledge that they are contributing to a healthy lifestyle.

The change in sales outlets is closely linked with the growing role of online platforms. As commerce moves from the physical space to cyberspace, this may impact on consumer behaviour too. Choice increases, and online price comparisons force intensified competition and therefore prices are closer to the marginal costs. It is difficult to measure the inflationary impacts of digital platforms because any such assessment would need to take account of the decrease in consumers' own costs. Just think about how, if we wanted to buy a car in the past, we had to travel to other towns, assess what was on offer and make lots of telephone calls. Nowadays we can find out about offers and prices in just a few minutes by using a smart device. To what extent is the convenience of e-commerce reducing our costs? Finding the answer to this important question will take us a step closer to identifying and understanding inflation biases.

The next set of issues concerns how to treat new products and the qualitative changes they have introduced; after all, waves of innovation over the past decade have resulted in substantial improvements in product quality. The price of digital devices (especially as calculated per unit of computing) is falling sharply, but statistical measurements are unable to capture this accurately (*MNB 2017*). Examining the inflationary impacts of digitalisation and digital products has been increasingly popular because the internet has provided analysts with big data as a tool: simply sitting in front of their computers, analysts can gather huge amounts of (price) information from the numerous online stores of the world. There are currently two major projects focusing on the calculation of online inflation: the Billion Prices Project (BPP) launched in 2008 as a cooperation between MIT and Harvard Business School (*Cavallo – Rigobon 2016*), and the Adobe Digital Price Index, which was started in 2014 as a part of the Adobe Digital Economy Project (*Goolsbee – Klenow 2018*). These could revolutionise the measurement of prices. Research has shown (*Goolsbee – Klenow 2018*) that the digital price index could be as much as 2.5 percentage points lower than the inflation measured in official statistics. Their results show that the difference between online and official statistics is the greatest (approximately 10 percentage points) in the price of computers (*Figure 15*).

Figure 15
Computer price inflation in the USA as measured based on official vs online data



Source: Adobe Digital Price Index, Goolsbee – Klenow (2018)

Another problem is that new digital devices are added to the statistics with some delay, so the steep price fall observed in the early stages of the life-cycles of these products is not captured, which results in a downward distortion of the price index (*OECD 2019b*). This is augmented by the fact that new products are appearing with ever increasing frequency in today's digital age.

The empirical results of examining conventional biases primarily cover the United States and the developed countries. Literature is dealing with the newer types of biases only in a qualitative way so far; only the differences between online and offline price indices are quantifiable (*Table 1*). Estimates suggest that the inflation biases may be significant, potentially as high as 2.5 percentage points.

Table 1
Estimated extent of consumer price index bias
(percentage points)

	Boskin Commission (1996)	***Gordon (2006)***	***Yörükoglu (2010)***	***Kurzweil (2005)***	***Goolsbee – Klenow (2018)***
	USA	**USA**	**Advanced economies**	**USA**	**USA**
Substitution between products	0.15	0.4*	0.1		
Substitution within products	0.25		0.1		
Sales outlet changes	0.1	0.1	0.1		1.3
New products and changes in quality	0.6	0.3	0.5	1.0–1.5	1.5–2.5
Total	**1.1**	**0.8**	**0.8**		
Estimated band	**0.8–1.6**		**0.5–2.0**	**1.0–1.5**	**1.3–2.5**

*Note: *The total of substitutions within products and between products. The bias calculated in the Boskin Report relates to 1995–1996, whereas Gordon's estimate applies to 2000–2006. Yörükoglu (2010) includes the United States as well as Japan, Germany, the United Kingdom and Canada in the developed countries' average. The estimate period of Goolsbee – Klenow (2018) is 2014–2017.*

Source: Boskin Commission (1996), Gordon (2006), Yörükoglu (2010), Kurzweil (2005), Goolsbee – Klenow (2018)

In the digital world of the 21st century, the role of 'bundling' is not insignificant either. Digital devices have ever more functions, replacing what had previously been separate products. Think of your mobile telephone: a single 'smart' device incorporates a camera, a video camera, books for your entertainment and all the motoring maps of the world plus up-to-date navigation and a database of related information. It would take quite a statistician to devise a consumer basket and a price index that reflects, without bias, all the price cuts, substitutions and quality improvements originating from such bundling!

The 'pricing' and appearance of free content primarily affects the prices of services. Free content is closely linked to digital products and some of its fundamental characteristics are that

1) it is not competitive: its consumption does not exclude others from consumption and, due to the network effect, its value rises as the number of users increases,

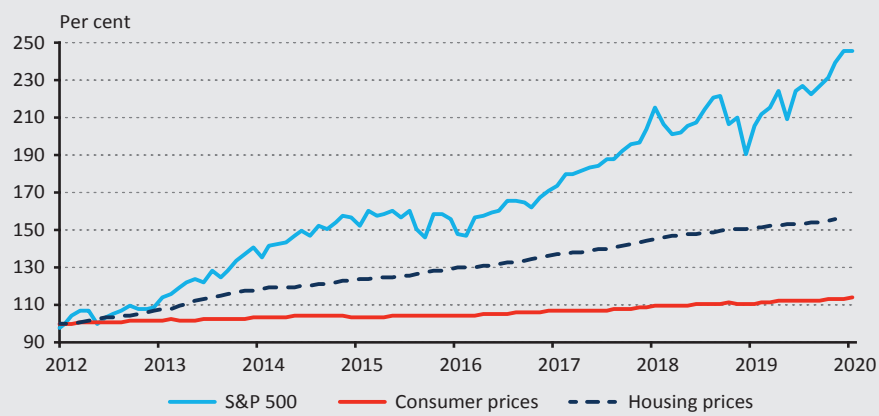
2) it can be multiplied at marginal cost, and

3) it is not tied to location and, mostly, is not tangible (*MNB 2017*).

Today we are increasingly using services that are practically available for free. Examples include the Google search engine, the videos available on YouTube and the Facebook social media platform. Their impacts are currently not measured yet, or are significantly under-measured.

And finally, mention should be made of the products omitted in the official statistics of prices, such as housing prices and financial instruments. By purchasing a home, you buy a long-term service, namely the ability to live somewhere. While most countries do not include these assets in their official statistics (or not with standard methodology), taking a look at the development of their prices reveals something of interest in itself. When consumer prices rise moderately, the price of homes and money market instruments will rise continually and significantly. *Figure 16* captures information relating to the United States, but a similar phenomenon may be seen in most regions of the world. The diagram suggests that the ultra-loose monetary policy of central banks in the developed world has driven asset prices up, meanwhile its impact on the real economy has remained subdued.

Figure 16
Changes in consumer, housing and equity prices in the USA (January 2012 = 100)



Source: Federal Reserve Bank of St. Louis

Overall, inflation biases originate from two sources: one is the omission of products, whereas the other group includes the fundamental biases that have been with us for a long time. If these biases could be eliminated, we would observe a lower rate of inflation, which could then result in higher growth in real GDP. The discussion of that matter would be the subject of another paper, it is not addressed here.

6. Summary and conclusions

In a highly timely move, several major central banks have announced a thorough review of their inflation targeting systems in recent months. Official statistics show that consumer inflation in the developed world has remained consistently below central banks' target rates for almost a decade, in spite of the extraordinary efforts of these central banks. If central banks miss targets permanently, they may incur credibility problems and, over time, this could erode the social acceptance of their decisions. One first step in the reconsideration of inflation targeting frameworks is correctly identifying new types of bias in the measurement of inflation and understanding the new patterns determining the changes in consumer prices.

From time to time, economists and economic policy would monitor different factors, which underlay their understanding of the changing of prices. In the pre-crisis period, the two pillars of inflation thought and theory were the quantity theory of money and the Phillips curve, which lost some of their relevance following 2008/2009. In addition, the role of the traditional factors explaining inflation also decreased: exchange rate pass-through to inflation decreased in the developed countries, the link between prices and wages weakened, and the Balassa–Samuelson effect no longer functions in today's globalised world.

The new trends of the post-crisis period are digitalisation and technology, demographics, globalisation and climate change; these also shape current economic thinking. As life expectancy rises in most advanced countries and the age composition of the population is transformed, these demographic processes are also changing inflationary impacts. The current consensus among analysts is that globalisation and digitalisation, and the technological progress achieved parallel to this, all point towards a decrease in inflation. The results published regarding the economic impacts of climate change are still uncertain, but the phenomenon and its effects are connected to demographic processes and technological innovation as well.

In the 21st century, when a large number of new developments and trends are shaping inflation and macroeconomic processes, it is crucial that the traditional measurement methodologies face these new challenges and integrate them. Besides the legacy problems in measurement such as product substitution or quality changes, the age of big data is bringing in new challenges such as the

emergence of digital products, the shift of commerce from traditional venues to platforms, the 'pricing' of free content and the inclusion in the statistics of currently omitted products and services, for instance housing prices and financial instruments. These measurement challenges may impact not only on inflation but on other macroeconomic indicators too.

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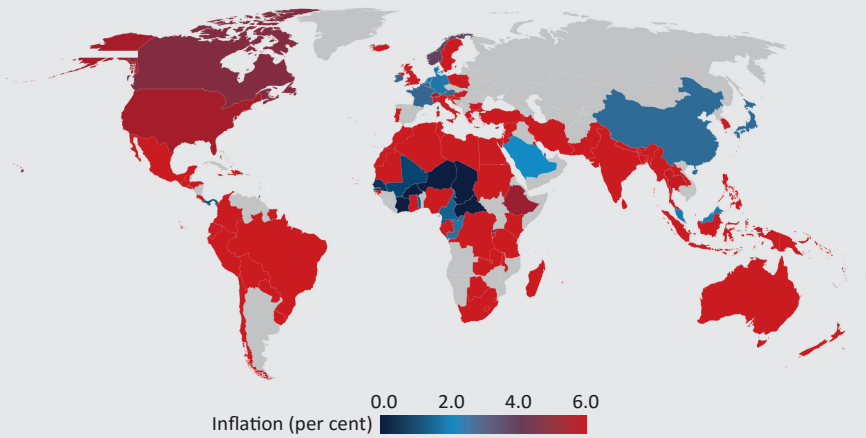
Annex

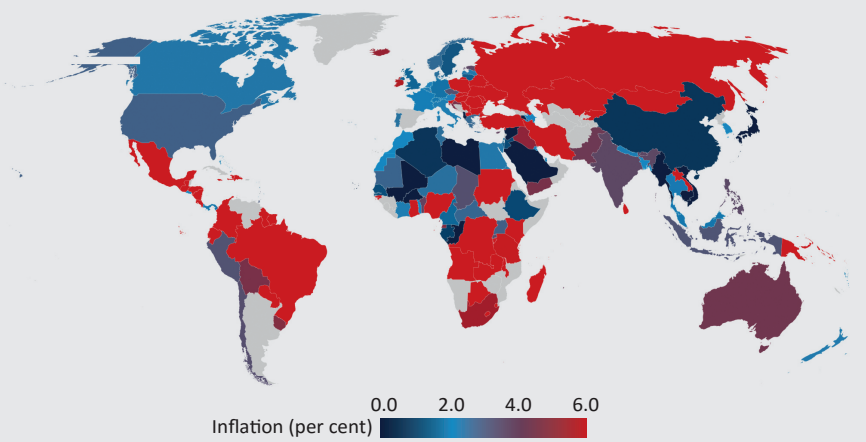
Figure 17
Consumer inflation in the world in 1990



Note: Annual change. Minimum: –0.8 per cent, maximum: 7,481.7 per cent. Data is not available for the countries shown in grey.

Source: World Bank

Figure 18
Consumer inflation in the world in 2000



Note: Annual change. Minimum: –3.8 per cent, maximum: 513.9 per cent. Data is not available for the countries shown in grey.

Source: World Bank