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Central banking in times of technological progress

Speech by Yves Mersch

Member of the Executive Board of the ECB

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There have been many significant advances in technology over the three and a half centuries that central banks have existed: railways, electrification, computerisation, and the internet to name but a few. Each of these great waves of technological revolution has transformed how economies function. While not all have had such a marked impact on central bank operations, we have nonetheless changed a great deal over the past 350 years, and should expect to do so in the future.

Given the uncertain impacts of technology, central banks should react prudently, and in the same forward-looking fashion that we implement policy. In my mind, there are three key responses of central banks to technology:

- *adapt* our policies to take into account technology-driven changes in the real world,

- *adopt* appropriate technology that enables us to best carry out our functions. As I will highlight throughout my remarks today, appropriate does not always mean the newest or most fashionable technology. Each new advance must be carefully and prudently assessed for its potential impact.
- *anticipate* technological risks to our operations.

With these three key responses in mind, I will consider the challenges – and opportunities – arising from technology to our mandate for price stability, central banks' role in payment systems, and safeguarding our operations in the internet age.

Price stability

The first important consideration for monetary policy relates not to any particular technology, but to the overall rate of technological progress. As the technological frontier shifts outwards, and that knowledge diffuses across the economy, overall productivity increases. That increased productivity affects the rate of return on investment and hence the level of real equilibrium interest rates.

Since monetary policy aims to vary short-term real rates around that equilibrium to meet our price stability mandate, changes in the overall rate of technological progress affect the interest rates central banks set. As such, policymakers need to adjust policy settings to adapt to changes in the real economy.

Setting policy according to a fixed rule with pre-determined coefficients on inflation and the output gap is at the best of times likely to lead to sub-optimal policy settings, given the uncertainties in measurement of the output gap. But in times of technologically driven changes in economic relationships, such

a rule could potentially result in interest rates that are wholly inappropriate for the economy and inconsistent with our mandate for price stability.

Yet that is not to say that different policy tools are all inappropriate. The past decade has posed a number of challenges for policymakers. For some observers, there appears to have been a secular fall in measured productivity growth[1] and equilibrium real rates[2] across advanced countries. Lower equilibrium rates reduce the room for manoeuver that central banks have to lower rates and still remain above the effective lower bound. Other observers attach more attention to measurement of productivity changes due to technological progress and globalisation and hence warn against hasty changes to targets and objectives.

At the same time, interbank markets in the euro area became fragmented along national lines during the crisis, threatening the transmission of monetary policy.

The various so-called unconventional monetary measures undertaken by the ECB and other central banks throughout the crisis are a good example of adapting policy to changes in the real economy. Forward guidance, asset purchases, negative nominal interest rates and lending schemes that incentivise banks to increase lending, such as the targeted longer-term refinancing operations, were all designed to combat the challenges of the period. Such policies were seen as

[1] See, e.g., Gordon, R. (2016), The Rise and Fall of American Growth: The US Standard of Living since the Civil War, Princeton University Press. It is worth noting that others contest the slowdown, arguing it relates to measurement error, e.g. Brynjolfsson, E. and A. McAfee (2011), Race Against The Machine: How the Digital Revolution is Accelerating Innovation, Driving Productivity, and Irreversibly Transforming Employment and the Economy. Digital Frontier Press.

[2] See , e.g., evidence presented in Constâncio, V. (2016), "The challenge of low real interest rates for monetary policy", Lecture at the Macroeconomics Symposium, Utrecht School of Economics, 15 June.

appropriate – being both necessary and proportionate responses by central banks to fulfil their mandate for price stability. But as conditions normalise, it is unlikely that these policies will remain necessary.

While my comments so far about technical progress in aggregate reflect a perennial challenge for central banks, current technological progress poses a particularly acute challenge because of its direct impact on the price-setting behaviour by businesses that underlies the inflationary process. Improvements in logistics have permitted the growth of global value chains, and e-commerce has revolutionised the transparency of pricing within and across countries. These technological advances can affect how domestic inflation reacts to shocks, the pass-through of exchange rate movements into inflation and the domestic impact of global developments and inflation.

These factors pose their own issues for the measurement of inflation. While that generally falls under the jurisdiction of statistical institutes, central banks have clear interest in engaging with methodological decisions given our mandate for price stability. Without wishing to devote too much time to technical details of index construction, allow me to highlight some of the issues.[3]

Technological progress has resulted in the creation of products such as smartphones and internet service providers that had no equivalent in the past. And the conceptual foundation of inflation being the annual change in prices is challenged when

[3] For a more detailed analysis of issues relating to index calculation, see Diewert, W. E. (1998), "Index Number Issues in the Consumer Price Index", *Journal of Economic Perspectives*, 12(1): 47-58 and von der Lippe, P. (2007), Index Theory and Price Statistics, Peter Lang, Frankfurt am Main.

some electronic articles have a shelf-life of less than a year. This is particularly true when part of the consumption value of the good in question is being the latest edition. Heavy discounting of the now less fashionable older editions could create downward bias in traditional indices.[4]

Similarly pricing online services poses a number of challenges. For example, in the past consumers would buy premade package holidays from a travel agent. Nowadays, online services permit households to create their own packages. This task is more and more outsourced by the agencies, i.e. they reduce their cost; and accepted by the customers. Measuring – and pricing – the value of that service is not always transparent. This complicates the proper inclusion of the economic activity undertaken into national accounts. Indeed, in the absence of a measurable transaction, it would normally be beyond the scope of consumer price indices.

Some internet services do not even have a monetary charge, but customers pay via providing data – sometimes without being aware of the full extent of their payment. Search engines and other portals are nominally for free, but create revenue through advertising, paid ordering of search results and commissions from linking customers to businesses.

A further challenge for price indices arising from internet sites is their ability to tailor individual prices to the consumer – two people looking at the same website at the same time may be offered two different prices. As indeed does the speed at which

[4] The direction of the bias for the aggregate index is less certain. Broda, C. and Weinstein, D. (2010), "Product Creation and Destruction: Evidence and Price Implications", American Economic Review, 100 (3): 691-723, find that failing to take into account product creation across the index creates an upward bias to traditional "fixed good" indices.

prices change. It was not that long ago that a hotel would post its prices for the year ahead and leave them fixed, whereas now hotels dynamically manage occupancy through changing room prices perhaps even several times in one day.

Of course, change in consumption habits and expenditure patterns are not a particularly new problem for statistical agencies to deal with. It has long been recognised that regularly updating weights and the goods and services included in the basket results in an index that better describes the prices faced by consumers. Consumer price indices, including the Harmonised Index of Consumer Prices used in the euro area, have already made large strides in adapting their methodology to account for changes in technology.

And technology has itself been a benefit in price collection. Gone are the days of price collectors walking through shops with a clipboard with reams of paperwork requiring multiple input steps. Price collection on the ground is now carried out with electronic tablets directly updating databases, and the opportunity to use web scraping technology has facilitated a much cheaper and widespread source of price quotes. Research can now be carried out on data sets not of hundreds of price quotes, but of a billion.[5] The use of scanner data has enabled a much greater idea of not only more granular purchases, but also seasonality in purchases.

But the technological changes to price and wage setting behaviour have much deeper relevance for central banks than just the measurement of inflation. The speed and extent that inflation reacts to shocks – both domestic and global – affects

[5] Cavallo, A. and R. Rigobon (2016), "The billion prices project: using online prices for measurement and research", *Journal of Economics Perspectives*, 30(2): 151-78.

the optimal response of monetary policy to those shocks. Allow me to give a few examples of how technology can affect the price-setting process and the economy's reaction to shocks, focusing on e-commerce.

E-commerce can erode the monopolistic and monopsonistic power of suppliers of goods and services, reducing mark-ups. Such a change in mark-ups can be viewed as a flattening of the Phillips curve, meaning a given change in the output gap has a weaker impact on inflationary pressures. Conversely, e-commerce may result in suppliers changing prices more frequently.[6] As I mentioned earlier, there is certainly evidence of this happening in certain sectors. Partly this is due to lower menu costs for producers, but also lower search costs for consumers increases the likelihood of them switching supplier and hence increases the opportunity cost of being away from the optimal price. More frequent price changes result in a steeper Phillips curve – prices react more quickly and stronger to changes in output.

At the same time, e-commerce may restrict the ability of businesses to set prices that deviate substantially from those of large online retailers.[7] So prices may change more often, but there may be a greater clustering of prices, which in turn may restrict the ability of prices to reflect idiosyncratic shocks. Furthermore, the dominance of certain online retailers, which may potentially be reinforced by the algorithms of search engines, may lead to market power and stifling of competitive forces over the longer term.

[6] Gorodnichenko, Y. and O. Talavera (2014), "Price setting in online markets: basic facts, international comparisons and cross-border integration", *NBER Working Paper*, No. 20406.
[7] Cavallo, A. (2017), "Are online and offline prices similar? Evidence from large multi-channel retailers", *American Economic Review,* 107(1): 283-303, finds price levels are identical around 72% of the time.

Overall, the impact of e-commerce on the slope of the Phillips curve is uncertain, and studies have in general struggled to find large effects on annual inflation.[8] Given the overall difficulty in estimating the slope of the Phillips curve, this is not entirely a surprise. And beyond just e-commerce, the development of global value chains[9] facilitated by technology could potentially change the influence of global inflation factors on domestic inflation[10] and the degree of exchange rate pass-through.[11]

As with the measurement of consumer price indices, the greater availability of more granular data has enabled a much greater understanding of how businesses set prices. But while policymakers should adapt policy to take into account changes in the underlying price-setting process, we should exercise due prudence, given the range and uncertainty surrounding model estimates.

And the effects of technology run deeper than just price setting. Email, videoconferencing, secure VPN[12] connections, and outsourcing across countries enable services to be provided from distance, and permit a greater degree of flexibility in working practices. It is a notable socio-economic shift in the interaction between employers and employees.

[8] See, e.g. Lorenzani, D. and J. Varga (2014), "The economic impact of digital structural reforms", *European Commission Economic Papers*, No. 529.
[9] For a more detailed discussion of the impact of global value chains see ECB (2017), "Domestic and global drivers of inflation in the euro area", *Economic Bulletin*, Issue 4 : 72-96.
[10] Ciccarelli, M. and B. Mojon (2010), "Global Inflation", *The Review of Economics and Statistics*, 92(3): 524-535 find that a large proportion of domestic inflation rates in 22 OECD countries can be explained by global factors. Parker, M. (2017), "Global inflation: the role of food, housing and energy prices", *Working Paper Series*, No 2024, ECB, extends the analysis to a much larger sample of 223 countries and territories, showing the influence is particularly strong in food and energy prices.
[11] For example, Amiti, M., Itskhoki, O. and J. Konings (2014), "Importers, exporters and exchange rate disconnect", *American Economic Review*, 104(7): 1942-78, find that larger shares of imported intermediates in production influence the degree of price pass-through from exchange-rate movements.
[12] Virtual Private Network.

In the labour market the internet allows for more services being offered with less intermediation at lower prices. Fragmentation of labour time is shown in the diverging results of compensation per employee and compensation per hour worked.

For some workers this is a positive development,[13] allowing them to participate in the workforce where previously they may have been unable. But for others, the greater individualisation of roles can lead to insecurity, in turn affecting households' income and spending. More individualised roles can also weaken the ability of collective bargaining to maintain the labour share of income.[14] These changes combined could lower the NAIRU,[15] changing the Phillips curve relationship between unemployment and wage pressure, and hence how monetary policy should react.[16]

Payment systems

The second area where I wanted to discuss the impact of technology on central banks is that of payment systems. Let me begin with cash, something that central banks have issued since their inception. For cash to carry out its roles as a medium of exchange and store of value, the public has to have trust in its integrity.

[13] Bloom, N., Liang, J., Roberts, J. and J. Zichun (2015), "Does working from home work? Evidence from a Chinese Experiment", *Quarterly Journal of Economics*, 130(1): 165-218 find a 13% increase in productivity of workers who work from home.
[14] International Monetary Fund (2017), "Understanding the downward trend in labor income shares", *IMF World Economic Outlook*, April.
[15] NAIRU = Non-accelerating inflation rate of unemployment. The NAIRU refers to a level of unemployment below which inflation rises.
[16] For a more detailed discussion of the impact on wages, see Haldane, A. (2017), "Work, wages and monetary policy", Speech at the National Science and Media Museum, Bradford, United Kingdom, 20 June.

To maintain that integrity and protect the currency from counterfeiters, central banks have for centuries not only adopted innovations at the cutting edge of printing technology to protect their notes from counterfeiting, but actively driven innovation in that area. Our latest €50 note – issued earlier this year – is no exception, incorporating an enhanced range of security features. Such technological adoption is wholly appropriate in this case, where ceding the technological high ground to criminals risks undermining the currency.

Cash is the only central bank liability available to the public. It maintains a tangible link between the general public and the central bank, a link which is important for maintaining trust between the two. Of course, several private sector payment instruments and systems are already well established: credit cards, direct debits and online payments to name but a few. More recent developments include payment methods based on smartphone technology, mobile wallets and investigations into the use of distributed ledger technology.

These technological developments have encouraged some to argue for the abolition of cash. Broadly speaking, those arguments fall into three camps: overcoming the restrictions on monetary policy arising from the zero lower bound, frustrating the actions of criminals by eliminating the primary means of illicit payments and reducing the high costs of cash storage, issuance and handling faced by the financial sector.

I have to admit some scepticism about these arguments. The various unconventional measures I mentioned earlier that central banks put in place during the past decade have proven sufficient to meet the challenges of low inflation and low

equilibrium rates. The United States has already begun to tighten policy. In the euro area, while our cycle is further behind, we already witness a broad-based and resilient recovery.

While being able to set significantly negative rates may work smoothly in an economic model, I am less certain how the public would react, particularly given the experience of millennia of positive nominal rates. Not only would such rates be deeply unpopular, there may be unintended changes in behaviour that would dampen the effectiveness of the measure.

Given the overall level of uncertainty of data and economic models, policymakers should act in a prudent fashion and only take actions that are necessary for the fulfilment of the price stability mandate and proportionate to the challenge in hand. To my mind, the abolition of cash for monetary policy purposes does not pass the appropriateness test.

In terms of the cost savings from new technologies such as the distributed ledger, I would again add caution. Far more detailed research is needed into the most beneficial system for all parties, and not just for financial institutions. As just one example, suppose central banks stopped providing cash and instead shifted to just providing Digital Base Money (DBM) – an electronic claim on the central bank. Would the system involve each individual having an account at the central bank, or involve a decentralised system where each individual has an electronic wallet and the central bank is unaware of transactions that take place. Either system could be

implemented using a distributed ledger, but the set up would be quite different in each scenario.[17]

In any case, just as cash has a number of technological safeguards to protect from counterfeiting, DBM would require significant safeguards to protect individuals from theft and from loss of personal information. Prudence should underpin our decision on what technology to adopt. Adopting untried technology that ultimately proves unreliable could seriously endanger public trust in the currency and in the central bank. Any new payments system technology should be rigorously tested before implementation, with due regulation and oversight thereafter.

As to the often stated link between cash and illicit payments, there is no evidence. Even the available anecdotal hints attribute only a relatively minor role to illicit activity compared to the overall honest use of cash as a private means of payment.

Moreover, for all the buzz currently surrounding new payment technologies, it is worth noting that cash, despite having been around for millennia, still remains popular. In the euro area, around 80% of transactions at point of sale are carried out in cash, and cash transactions account for around half the total value. For now, provision of physical cash remains an important role for central banks.

There may be a time in the future when the general public favour electronic money. Cash transactions are already a minority in some countries. In that future time, it would be

[17] The issues surrounding DBM are discussed in more detail in Mersch, Y. (2017), "Digital Base Money: an assessment from the ECB's perspective", Speech at the Farewell ceremony for Pentti Hakkarainen, Deputy Governor of Suomen Pankki - Finlands Bank, Helsinki, 16 January.

appropriate for central banks to adopt technology that best reflects the general preferences of the population. It is not our role to drive technological adoption in the general public, but to enable changing preferences to be fulfilled in a secure fashion. For that reason we test new technologies in laboratory environments with an array of partners.

Safeguarding our operations

Security is the final area I wish to consider today. What steps need to be taken to safeguard our operations from technological risks?

Banknotes and payment systems are not the only areas where technology creates risk for public trust in the central bank. Traditionally we have maintained strong physical security measures to protect our gold and currency reserves. In 1781, the Bank of England acquired and subsequently tore down the adjacent church St Christopher le Stocks, fearing that the spire could be seized by rioters and used as a platform to attack the Bank.

As a result of technology, potential attacks on central banks extend beyond the physical realm and can be launched from much further away than the building next door. Thick walls of a different kind are required to protect our valuable data from technological incursions. Recent examples of such incursions include payment systems being accessed and substantial funds being transferred; suspicions – since proven unfounded – of financial market trades occurring on the basis of hacking the electronic link between the central bank and newswires;

sensitive information being emailed accidentally to outside sources; and journalists breaking embargo on interest rate decisions.

Central banks are also vulnerable to more generalised technological risks. There have been a number of recent examples of computer virus outbreaks that have simultaneously disabled computer networks across a range of institutions in several countries. Were such a virus to affect the central bank's own network, there would be considerable operational risk. Similarly, the smooth functioning of payment systems could be threatened if those servers were affected.

Faced with this range of threats to our operations, central banks should regularly assess potential risks, and take measures to anticipate them. Anti-counterfeiting measures incorporated into our banknotes are designed to foil the most sophisticated counterfeiters. Measures put in place to protect our information should likewise aim to foil the most sophisticated assailants. Adopting the latest technological advances in security is not only appropriate, but vital.

Conclusion

Allow me to conclude.

Technological change is an integral driver of economic development. It is disruptive at times and impacts not only economies but also our societies. Central banks are not isolated from these processes.

Central banks are well advised to be prudent and forward-looking when approaching the respective challenges – just as they are when implementing monetary policy to honour their mandates.

Facing the uncertainties of technological change, central banks therefore should

1. *adapt* policies to take into account technology-driven socio-economic changes,
2. *adopt* appropriate technology that supports the various functions and tasks of a central banks, and
3. *anticipate* technological risks to our operations.

With these principles in mind, central banks can better manage the challenges stemming from technological change, even when it is disruptive. Used appropriately they can even help to improve our operations and efficiency.