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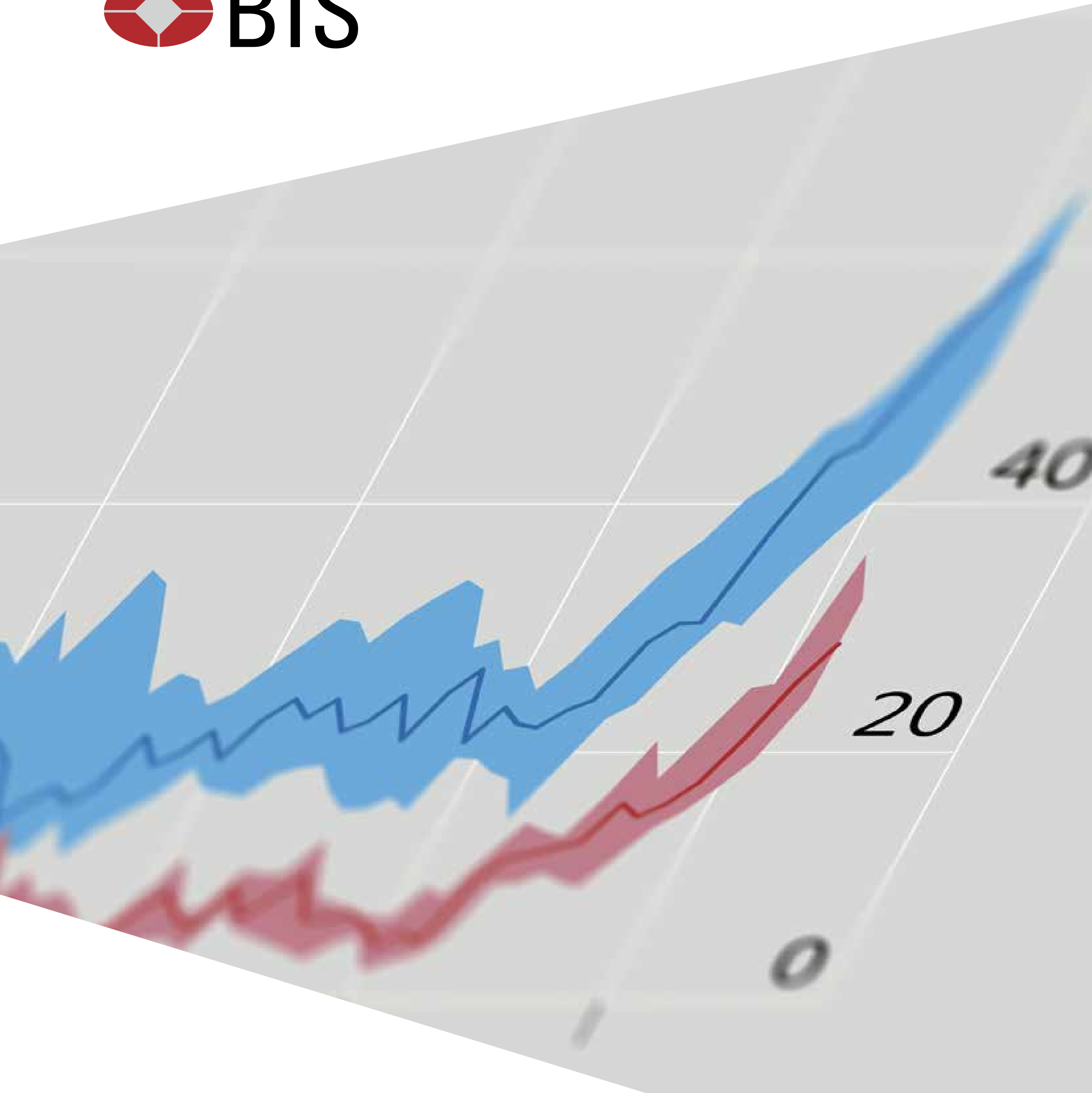

Annual Economic Report

June 2022

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June 2022

Promoting global monetary and financial stability

This publication is available on the BIS website (https://www.bis.org/publ/arpdf/ar2022e.htm).

ISSN 2616-9428 (print)
ISSN 2616-9436 (online)

ISBN 978-92-9259-570-8 (print)
ISBN 978-92-9259-571-5 (online)

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This Report went to press on 16 June 2022 using data available up to 30 May 2022.

A technical annex containing detailed explanations for the graphs and tables is included at the end of each chapter.

Conventions used in the Annual Economic Report

std dev	standard deviation
σ^2	variance
$	US dollar unless specified otherwise
’000	thousands
mn	million
bn	billion (thousand million)
trn	trillion (thousand billion)
% pts	percentage points
bp	basis points
bbl	barrel
lhs, rhs	left-hand scale, right-hand scale
sa	seasonally adjusted
saar	seasonally adjusted annual rate
mom	month on month
yoy	year on year
qoq	quarter on quarter
…	not available
.	not applicable
–	nil or negligible

Components may not sum to totals because of rounding.

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Country codes

AE	United Arab Emirates	FR	France	NI	Nicaragua
AL	Albania	GB	United Kingdom	NL	Netherlands
AR	Argentina	GH	Ghana	NO	Norway
AT	Austria	GR	Greece	NZ	New Zealand
AU	Australia	HK	Hong Kong SAR	PA	Panama
BA	Bosnia and Herzegovina	HN	Honduras	PE	Peru
		HR	Croatia	PH	Philippines
BE	Belgium	HT	Haiti	PK	Pakistan
BG	Bulgaria	HU	Hungary	PL	Poland
BO	Bolivia	ID	Indonesia	PT	Portugal
BR	Brazil	IE	Ireland	QA	Qatar
CA	Canada	IL	Israel	RO	Romania
CH	Switzerland	IN	India	RU	Russia
CL	Chile	IS	Iceland	RS	Serbia
CN	China	IT	Italy	SA	Saudi Arabia
CO	Colombia	JP	Japan	SE	Sweden
CR	Costa Rica	KR	Korea	SG	Singapore
CS	Czechoslovakia	KW	Kuwait	SI	Slovenia
CY	Cyprus	KZ	Kazakhstan	SK	Slovakia
CZ	Czechia	LT	Lithuania	TH	Thailand
DE	Germany	LU	Luxembourg	TR	Turkey
DK	Denmark	LV	Latvia	TW	Chinese Taipei
DO	Dominican Republic	LY	Libya	UA	Ukraine
DZ	Algeria	ME	Montenegro	US	United States
EA	euro area	MK	North Macedonia	UY	Uruguay
EE	Estonia	MT	Malta	VE	Venezuela
ES	Spain	MX	Mexico	VN	Vietnam
EU	European Union	MY	Malaysia	XK	Kosovo
FI	Finland	NG	Nigeria	ZA	South Africa

Currency codes

AUD	Australian dollar	KRW	Korean won
BRL	Brazilian real	MXN	Mexican peso
CAD	Canadian dollar	MYR	Malaysian ringgit
CHF	Swiss franc	NOK	Norwegian krone
CLP	Chilean peso	NZD	New Zealand dollar
CNY (RMB)	Chinese yuan (renminbi)	PEN	Peruvian sol
COP	Colombian peso	PHP	Philippine peso
CZK	Czech koruna	PLN	Polish zloty
DKK	Danish krone	RUB	Russian rouble
EUR	euro	SEK	Swedish krona
GBP	pound sterling	THB	Thai baht
HUF	Hungarian forint	TRY	Turkish lira
IDR	Indonesian rupiah	USD	US dollar
INR	Indian rupee	ZAR	South African rand
JPY	Japanese yen		

Advanced economies (AEs): Australia, Canada, Denmark, the euro area, Japan, New Zealand, Norway, Sweden, Switzerland, the United Kingdom and the United States.

Major AEs (G3): the euro area, Japan and the United States.

Other AEs: Australia, Canada, Denmark, New Zealand, Norway, Sweden, Switzerland and the United Kingdom.

Emerging market economies (EMEs): Algeria, Argentina, Brazil, Chile, China, Colombia, Czechia, Hong Kong SAR, Hungary, India, Indonesia, Israel, Korea, Kuwait, Malaysia, Mexico, Morocco, Peru, the Philippines, Poland, Romania, Russia, Saudi Arabia, Singapore, South Africa, Thailand, Turkey, the United Arab Emirates and Vietnam.

Global: all AEs and EMEs, as listed.

Depending on data availability, country groupings used in graphs and tables may not cover all the countries listed. The grouping is intended solely for analytical convenience and does not represent an assessment of the stage reached by a particular country in the development process.

No respite

Introduction

There is no respite for the global economy. Two years ago, it was shaken by the onset of the pandemic, as an overwhelming health crisis turned into an overwhelming economic crisis. While the after-tremors of the pandemic still reverberate, two new shocks hit home in the year under review: the unexpected resurgence of inflation and the tragic war in Ukraine. Last year's Annual Economic Report (AER) raised the prospect of a bumpy pandexit; bumps have turned out to be a one-two punch.

These tumultuous events are bound to have far-reaching consequences. Are we perhaps witnessing a regime change, from a low- to a high-inflation regime? Is the global economy flirting with stagflation? And are we seeing signs of an end to the post-World War II globalisation era? Meanwhile, the crypto universe is in turmoil, reminding us that there are important developments in the monetary system that we cannot neglect.

On the macro front, policy is facing daunting challenges. In some ways, they are not new; but in others, they are unique. As Mark Twain quipped, "History does not repeat itself, but it often rhymes." The world economy experienced stagflation in the 1970s, following a shift away from a low-inflation regime. The new element is that, against the backdrop of historically low interest rates, debt levels – private and public – have never been as high. This is far from inconsequential. Moreover, the monetary and financial system is in the throes of the digital revolution. This, too, albeit in a different way, is far from immaterial.

Our AER tackles these issues head-on. What happened in the year under review? What are the risks ahead? What can policy do? And where is the monetary system heading as the digital revolution proceeds? What vision should guide policy?

Never say never

Resilient but losing momentum and buffeted by non-economic forces: in a nutshell, this is how global growth evolved over the review period.

Growth proved resilient for much of 2021.

In fact, in 2021 as a whole, the world economy expanded at its fastest rate in almost 50 years. And the expansion was broad-based. This confirmed the unique nature of the Covid-19 recession. An artificial suppression of activity due to the health emergency gave way to a strong rebound once the containment measures were lifted. In addition, the outsize policy support, both monetary and fiscal, provided a major impulse. The scenario in which economic scars would have held back growth did not materialise.

Growth lost momentum as the review period progressed.

First was the spread of a new virus variant (Omicron) in late 2021, which prompted countries to put in place new containment measures. As it turned out, the impact was smaller than initially feared. The virus proved milder than expected and so did the necessary policy-induced restraint on activity. The main exception was China. The strict anti-Covid measures caused a major slowdown in growth, adding to the effect of regulatory measures designed to rein in the real estate sector.

Then was the outbreak of the Russia-Ukraine conflict in February 2022. Probably the most significant geopolitical event since the fall of the Iron Curtain, the war is first and foremost a humanitarian tragedy. But its near-term impact on economic activity is also substantial. The impact has not been felt so much through the sanctions-induced drop in Russia's GDP – although the imprint on world growth is material. Nor has it been felt, so far, through its direct financial consequences – although more may be in store (see below). Rather, it has operated mainly through soaring commodity prices – notably energy and food – as well as concerns about the war's broader ramifications.

This shock is inherently stagflationary. To be sure, its impact on growth is uneven across the world. Commodity exporters fare better than importers. But, for the world as a whole, the outcome is unambiguously contractionary. Since commodities are a key production input, an increase in their cost constrains output. At the same time, soaring commodity prices have boosted inflation everywhere, exacerbating a shift that was already well in train before the onset of the war.

Indeed, the most remarkable development during the review period was the return of inflation. The biggest challenge for central banks post-Great Financial Crisis (GFC) had been to lift inflation back to target. As events unfolded, however, what initially appeared a temporary blip, driven by Covid-induced idiosyncratic price adjustments, turned into a much broader surge, across prices and countries. By April 2022, three quarters of economies were experiencing inflation above 5%. Inflation was back, not as a long-sought friend, but as a threatening foe.

Just like most observers, we at the BIS did not quite anticipate the strength and persistence of the surge. To be sure, in last year's AER we did explore a plausible high-inflation scenario. In the end, however, the scenario fell short of reality.

Why the miss? Humility is in order. But probably the best explanation involves the confluence of three forces – an explanation that necessarily cannot do justice to cross-country differences (see Chapter I for details). First, the surprisingly strong rebound in aggregate demand, beyond what was implicit in the scenario. The huge policy stimulus combined with households' pent-up spending turbocharged activity. Second, a surprisingly persistent "pivot" or rotation of demand from services to goods. Although people did spend, they did not flock back to contact-intensive services, such as restaurants and hotels, as widely as expected. Finally, there were some surprising difficulties in adjusting supply. Their most visible manifestation are the "bottlenecks" that held back production around the world. Think, in particular, of those that hit raw materials and semiconductors as well as freight and transport. While, initially, the disruptions reflected primarily pandemic-related measures, demand strength then took over.

Bottlenecks in global value chains aggravated these constraints. Complex production networks, sprawling across the world and structured to cut costs, betrayed their fragility as the disruptions hit them. Moreover, firms started hoarding inventories as a precaution. The shift from just-in-time to just-in-case inventory management exacerbated shortages.

Against this backdrop, central banks started to normalise policy, albeit at speeds that partly reflected varying country-specific conditions. First off the blocks were several central banks in emerging market economies (EMEs), mostly in central and eastern Europe and in Latin America. Because of the slower recovery and a better inflation record, those in Asia moved later and more cautiously. Among advanced economies (AEs), the Federal Reserve was one of the first to respond as inflation pressures intensified. The ECB signalled that it would start removing accommodation later in 2022 while the Bank of Japan stuck to its exceptionally accommodative policy. The main exception was the People's Bank of China, which eased policy to support flagging growth.

Near-term prospects

What are the near-term prospects for the global economy?

Context is of the essence. For the first time in the post-World War II era, the global economy is facing the threat of higher inflation, and hence the need to keep it in check, against the backdrop of elevated financial vulnerabilities. Looming large among these are historically high debt levels, both private and public, and rich valuations, notably for residential property.

There is a narrow path ahead. It is possible to envisage a smooth resolution of the economic tensions. In this scenario, inflationary pressures ease spontaneously due to an end to bottlenecks alongside a reversal in the war-induced increases in commodity prices. This reduces the size of the required monetary policy tightening and mitigates the associated slowdown in economic activity – a soft landing. But the outcome could be less benign. The worst-case scenario would be stubborn inflation pressures that prompt a stronger tightening. This could trigger a larger slowdown, including a recession, alongside financial stress – a stagflationary hard landing.

Hence a natural sequence of questions. Will higher inflation become entrenched? How far could growth falter? Will the financial sector come under strain?

Inflation

Policy response aside, whether inflation becomes entrenched or not ultimately depends on whether wage-price spirals will develop. The risk should not be underestimated, owing to the inherent dynamics of transitions from low- to high-inflation regimes.

Three reasons stand out. First, we have already seen outsize and persistent increases in especially salient prices, such as those of food and energy. Households and workers' perceptions of inflation and expectations of its future evolution are especially sensitive to them. Second, given the broadening of price pressures, inflation in general has no doubt moved out of the zone of "rational inattention", within which it has little impact on behaviour, into that of sharp focus, in which it starts to influence behaviour more substantially. Finally, price-induced cuts in real wages are likely to prompt workers to seek to recoup the loss of purchasing power. Similarly, firms should find it easier to translate higher wages into higher prices given how generalised wage and cost pressures are.

We may be reaching a tipping point, beyond which an inflationary psychology spreads and becomes entrenched. This would mean a major paradigm shift.

These observations underscore some stylised features of the inflation process, as analysed in detail in Chapter II. For a start, low- and high-inflation regimes are very different animals. When inflation settles at a low level, it reflects mainly changes in sector-specific, or relative, prices as opposed to more synchronised ones. In addition, it exhibits self-equilibrating properties, as these price changes, including those of "salient" items such as oil and food, tend to leave only a temporary imprint on inflation. One reason is that, as the idiosyncratic fraction of price changes is greater, differences in the price indices that matter for individual agents – households and firms – are commensurately larger. Not only is economy-wide inflation less noticeable, it is also less relevant. High-inflation regimes are the mirror image of low-inflation ones. In particular, they don't exhibit self-equilibrating properties, price changes are much more synchronised and inflation is much more of a focal point for the behaviour of economic agents, exerting a major influence on it.

This also means that transitions from low- to high-inflation regimes tend to be self-reinforcing. As inflation rises and becomes a focal point for agents' behaviour, behavioural patterns tend to strengthen the transition. Agents redouble their efforts to protect themselves from losses in purchasing power or profit squeezes, both actual and, increasingly, prospective ones. And wage negotiations tend to become more centralised, while demands for indexation proliferate and contract lengths shrink.

Put differently, when changes in relative prices are large and persistent enough, they test the self-equilibrating properties of the low-inflation regime. All the more so if labour and product markets are tight, which puts further upward pressure on both prices and wages.

From this perspective, so far, the signs are not entirely reassuring. True, wage growth has been uneven across countries. It has been especially strong where aggregate demand pressures have been more in evidence, not least in countries that have made large terms-of-trade gains or have a history of high inflation. Hence the differences between Latin America and Asia. But in many countries, a substantial part, if not the bulk, of wage renegotiations are still to come. And in some of them demands for higher indexation and more centralisation of wage bargaining have already surfaced. Moreover, terms-of-trade losses may actually strengthen cost-push inflationary pressures with a lag: when the cake becomes smaller, the fight over it becomes bigger.

Growth

Two specific factors darken growth prospects at the current juncture: much of the impact of developments in commodity markets is still to be felt, and macro-financial vulnerabilities loom large. These factors matter in and of themselves. But they are especially significant against the monetary policy tightening under way.

So far, the effect of commodity market ructions has operated mainly through higher prices. It would become much bigger should supply constraints kick in as well.

As regards energy, embargoes and price caps are on the horizon or being implemented. Furthermore, investment in fossil energy sources has been remarkably subdued, not least owing to the uncertainty-fraught transition towards zero emissions.

As regards food, a crisis looms ahead. The war has wreaked havoc with the supply of staples, such as wheat, and of fertilisers, which will greatly curtail crop production. In addition, the tendency to cut food exports to favour the domestic market inhibits distribution across the world and discourages production. Finally, soaring food prices threaten to trigger major social and political unrest, especially in lower-income countries. A food crisis is a humanitarian calamity that may also have crippling consequences for the economy.

What about the conjunction of historically high private debt levels and elevated asset prices? Much will depend on the evolution of interest rates and their knock-on effects on financial markets, since high indebtedness heightens the sensitivity of expenditures and the risk of financial strains.

A simple, highly stylised statistical exercise developed in Chapter I sheds some light on this question, suggesting that the sensitivity of the economy to interest rates is substantial. At one extreme – used purely as an analytical reference – in a scenario in which interest rates are held constant, asset prices continue to rise alongside debt levels, pointing to a further build-up in vulnerabilities. In one in which interest rates follow the market-implied path, by 2025 GDP could be roughly 1.5% lower relative to the constant-rate baseline. And if they follow the steeper path of the early 2000s, by 2025 debt service ratios could climb back to their GFC levels while both house and equity prices would see steep declines. As a result, the shortfall of GDP relative to the baseline is around 3%.

Naturally, these results are purely illustrative. They are based on average relationships since the mid-1980s for a number of AEs and are subject to substantial uncertainty. That said, they provide a sense of the orders of magnitude involved and hence of the trade-offs faced by policymakers.

Moreover, macro-financial vulnerabilities need not weigh down on growth only if interest rates increase. This is the case in China, where the authorities have sought to contain the build-up of risks in the real estate sector – a key driver of growth for the country – so as to make growth more sustainable. Indeed, the combination of financial imbalances and stringent lockdowns casts a long shadow on China's growth prospects and hence on those of the global economy.

Financial system stress

Against this global backdrop, the resilience of the financial system will be tested. Here, while deeply interconnected, it is useful to make a distinction between banks and non-bank financial intermediaries (NBFIs).

Thanks to the wide-ranging post-GFC financial reforms, the banking sector is now in a much stronger financial position. Above all, banks are much better capitalised. This is what allowed prudential authorities to temporarily relax the regulatory and supervisory constraints in the early stages of the Covid crisis, thereby supporting economic activity.

But there is no room for complacency. For one, although banks' direct exposures to developments in Russia are comparatively small and manageable, indirect exposures are more opaque. More importantly, macroeconomic prospects are a major source of risk. Stylised simulations suggest that credit losses could be material. Based on past relationships, along the market-implied interest rate path, bank credit losses would be broadly in line with historical averages across AEs. But they would be substantially higher in the scenario in which interest rates rise more steeply.

Vulnerabilities in the NBFI sector are more significant. Not only do they matter for banks, as they represent potentially large and opaque exposures. The losses from the failure of a leveraged fund (Archegos) in 2021 are a case in point. These also matter in and of themselves. This was underscored by the financial market turmoil in March 2020. At the time, an abrupt "dash for cash" prompted massive central bank intervention to stabilise markets. Structural vulnerabilities in the form of hidden leverage and liquidity mismatches loom large in the asset management sector. Hence the urgent need to redouble regulatory efforts in this area.

Policy challenges

Just as the policymakers were breathing a sigh of relief with the end of the pandemic in sight, the flare-up of inflation and the Russia-Ukraine conflict have raised new and daunting challenges. It is useful to distinguish the near-term from the longer-term ones, although the dividing line between the two is quite fuzzy.

Near-term challenges

The overriding near-term challenge is to prevent the global economy from shifting from a low- to a high-inflation regime. In doing so, policymakers will need to limit the costs to the economy as far as possible and to safeguard financial stability. Some pain, however, will be inevitable. As historical experience has shown time and again, the long-term costs of allowing inflation to become entrenched far outweigh the short-term ones of bringing it under control.

This is not just an economic challenge about policy calibration; it is also, importantly, a political economy one. Ever since the GFC, and even more so following the Covid crisis, both monetary and fiscal policies have worked to boost economic activity. With inflation languishing stubbornly below targets, there was no obvious trade-off between easy policy and inflation. Indeed, fiscal policy was invoked more than once to relieve some of the burden placed on monetary policy. To be sure, trade-offs did not magically vanish. The exceptionally low interest rates that persisted for so long did contribute to the gradual build-up of financial vulnerabilities. But now trade-offs have come into view much more starkly.

Take fiscal policy first. The economic slowdown will further widen public sector deficits. While this will cushion the blow to economic activity, it will also further raise government debt from its historical peaks. And as the cost of living soars in the wake of the sharp increases in the prices of food and energy, pressures to provide additional support will mount. It is essential that this support be targeted and temporary so as not to endanger fiscal sustainability further. So far, however, governments have relied more on untargeted measures, which are more costly and harder to reverse.

For monetary policy, the self-reinforcing nature of transitions from low- to high-inflation regimes heightens the calibration difficulties (Chapter II). In general, the self-equilibrating properties of inflation in a well established and credible low-inflation regime allow the central bank to accept moderate, possibly persistent deviations, from narrowly defined targets. Indeed, this is desirable, since there is evidence that, in such a regime, monetary policy loses traction owing to the large role played by sector-specific (idiosyncratic) price changes. The more vigorous actions required would increase any associated costs, such as those of interest rates that remain exceptionally low for long. But, crucially, once the regime is tested hard, as it is now, the transition can gather speed. This puts a premium on a timely and decisive response – all the more so given the well known lags with which monetary policy affects expenditures and then inflation.

In such a context, two sources of uncertainty complicate the calibration.

The first concerns the evolution of inflation. The key problem is that leading indicators have not proved fully fit for purpose (Chapter II). The broadening of price pressures or the pickup in underlying measures of inflation can help, but they provide relatively little information beyond short horizons. Measures of inflation expectations can also be useful, but they have their own drawbacks. Those derived from financial asset prices need not reflect the expectations of the economic agents that matter most – workers and firms. And those derived from household and firm surveys tend to be very backward-looking. In addition, more formal models, which are necessary to chart the inflation path at longer horizons, are least reliable precisely when needed most – during transitions. So far, these sets of indicators are sending mixed signals. Broadening price increases and higher expectations provide reasons to worry, at least for the near term; models tend to paint a more benign picture, but arguably an overly rosy one.

By far the most reliable indicator is evidence of wages chasing prices – second-round effects. But by the time these are clearly visible, inflation may already be becoming entrenched. Hence the need to focus on softer information, such as signs of changes in inflation psychology and attitudes to price increases.

The second source of uncertainty concerns the strength of policy transmission. As discussed, private debt levels at historical peaks and elevated valuations could make expenditures especially sensitive. And after a long spell of unusually low interest rates and ample liquidity, financial markets could overreact. While, so far, financial conditions have tightened, sharper adjustments could be in store. In fact, inflation-adjusted (real) interest rates have been falling as inflation has picked up.

Hence a policy dilemma opens up. Uncertainty about the evolution of inflation, about financial market reactions and about expenditure decisions may counsel caution. But the risk of inflation becoming entrenched calls for a more pre-emptive and vigorous response. In navigating this dilemma, good communication may help, but only up to a point. The overriding priority is to avoid falling behind the curve, which would ultimately entail a more abrupt and vigorous adjustment. This would amplify the economic and social costs of bringing inflation under control.

Against this backdrop, and cross-country differences aside, EMEs are especially vulnerable. They are more at the mercy of global financial conditions, which are likely to tighten further, including through dollar appreciation, and they have less room for policy manoeuvre. So far, capital flows have been less disruptive than in previous episodes, such as the taper tantrum. No doubt, more comprehensive policy frameworks have helped, involving a judicious reliance on foreign exchange intervention and macroprudential measures. And so has pre-emptive tightening where incipient inflationary pressures were stronger. Also helpful is the fact that the share of foreign investors in domestic markets has already shrunk. But the tougher tests may still lie ahead.

Longer-term challenges

As policymakers struggle to meet the urgent near-term challenges, they should not lose sight of a key longer-term one – regaining policy safety margins. As discussed in detail in last year's AER, over time the room for policy manoeuvre has narrowed substantially. Government debt levels are at historical peaks, interest rates, both nominal and real, have been falling to historical troughs and central bank balance sheets have risen to levels previously seen only in wartime. The recent tightening of monetary policy has, so far, only marginally changed this picture, at least in AEs. Economies operating without safety margins are exposed and vulnerable.

The current challenging environment does have one silver lining: it provides an obvious opportunity for monetary policy to finally normalise. That said, it has also highlighted a conundrum. Since regaining policy headroom is a joint task, the two policies tend to work at cross purposes along the normalisation path. Now, monetary policy tightening is materially raising the government's financing costs at a time when further demands on spending, both short- and longer-term, are growing.

Moreover, where central banks have engaged in large-scale asset purchases, higher interest rates will also reduce central bank remittances to the government (see last year's AER). These central banks have de facto replaced long-term debt with debt indexed to the overnight interest rate – the rate on bank reserves. As a result, in the largest advanced economies, as much as 30–50% of marketable government debt is effectively overnight. In the process, losses could heighten political economy risks for central banks.

In part, this long-term joint normalisation challenge is itself the reflection of a deeper problem. For far too long, there has been a temptation to turn to fiscal and monetary policy to boost growth, regardless of the underlying causes of weakness. For fiscal policy, in particular, loosening during contractions has not given way to consolidation during expansions. The temptation to postpone adjustment has been too strong. Such a strategy has arguably generated unrealistic expectations and demands for further support.

As discussed in more detail in Chapter I, the only way of promoting robust long-term growth is to implement ambitious structural reforms. Unfortunately, such reforms have been flagging for too long. These reforms are more important than ever at the current juncture, given the signs that globalisation may go into reverse, partly due to geopolitical considerations.

The future monetary system

Digital innovation will also surely play a key role in the long-term growth story, not least through its impact on the shape of the future monetary system (Chapter III). Policymakers face both urgent and important tasks. Some of these important tasks do not always figure in the breathless commentary of market observers. A critical one is to put in place the components of a future monetary system that serves the public interest.

As a case in point on the twin dimensions of urgent and important policy challenges, this AER comes out at a time of turmoil in the crypto universe. The recent implosions of the Terra stablecoin and its twin coin Luna are only the most spectacular collapses in the crypto sector. As we write, many lesser-known coins have seen their prices drop by more than 90% relative to their peaks last year. Traditional financial stability concerns stemming from run risk are an urgent policy challenge. However, focusing on prices diverts attention away from the deeper structural flaws in crypto that make it unsuitable as the basis of a monetary system that serves society. We should also keep these longer-term structural issues on our radar.

For one, the prevalence of stablecoins in the crypto universe indicates a pervasive need for crypto to piggyback on the credibility of central bank money. Only the central bank can provide the nominal anchor that crypto craves. Crypto started by turning its back on central bank money, but it has quickly rediscovered the need for the unit of account function of central bank money. The same goes for the medium of exchange function of money. Stablecoins are used to facilitate transactions across more than 10,000 crypto coins, all competing for the attention of speculative buyers.

The proliferation of coins also highlights the fragmentation of the crypto universe, with many incompatible settlement layers jostling for a place in the limelight. Gone is any pretence that money serves a coordination role. Money is the pre-eminent example of network effects, which give rise to the virtuous circle of greater use and greater acceptance. Rather than a single money gaining general acceptance, thousands of different coins proliferate. Under the plausible-sounding motto of "decentralisation and democratisation of finance", crypto platforms have mushroomed, all claiming to offer settlement of financial transactions. But the congestion and high costs of these platforms have only opened the way for new entrants, which cut corners on security in order to offer greater transaction capacity.

Money and its network effects should have the property of "the more, the merrier": the more money meets general acceptance, the more useful it becomes in serving the public interest. Instead, the crypto universe heads in the opposite direction: "the more, the sorrier". The only participants who profit are the crypto insiders, who extract rents from the speculative market on the back of new entrants left holding the bag.

Having said all of this, the rise of crypto highlights the place of technology in the popular imagination, and its galvanising role in debates on the shape of things to come. In spite of its well documented flaws, crypto offers a tantalising glimpse of potentially useful technical features that could enhance the capabilities of the current monetary system. Notable examples include composability and automatic execution, which represent features with a potential to deliver instantaneous settlement of transactions and transform the efficiency of economic arrangements.

The vision for the future monetary system set out in Chapter III is a fusion of these enhanced technical capabilities with the core of trust provided by central bank money. The traditional strengths of the two-tier system and the division of labour between the central bank and the private sector can be translated into a setting with wholesale CBDCs, tokenised deposits and other tokenised securities or assets. The classical notion of settlement via the book entries of intermediaries can find new expression in DLT platforms on which tokens are transferred in settlement. The economics remain the same, but the technological medium is transformed. Retail fast payment systems with interoperability powered by application programming interfaces, or APIs, bear a strong family resemblance to retail CBDCs.

The metaphor for the future monetary system is that of a tree. With a solid trunk provided by the central bank, the tree hosts a rich and vibrant ecosystem of private sector service providers serving users in order to meet their economic needs. And this ecosystem is rooted, figuratively speaking, in settlement on the central bank's balance sheet.

Central banks, as guardians of the monetary system, are embarked on a long journey to fulfil the vision of making it versatile and robust. This journey is necessary to put in place arrangements that anticipate future developments rather than merely react to past developments. So, while the sound and fury of collapsing crypto prices grabs all the attention, it is incumbent on us in the central bank community to look ahead to these longer-term goals. For if we do not start today, we will never get there.

I. Old challenges, new shocks

Key takeaways

- Two powerful forces – the Covid-19 pandemic and the Russian invasion of Ukraine – shaped economic outcomes over the past year.
- Growth was resilient, at least until the outbreak of the Russia-Ukraine conflict. Inflation rose to multi-decade highs against a backdrop of persistently goods-intensive demand and constrained supply.
- Stagflation risks loom large, owing to high inflation, the war in Ukraine and slower growth in China. Pre-existing macro-financial vulnerabilities magnify the risks, which could disrupt financial systems and strain emerging market economies.
- The most pressing monetary policy task is to restore low and stable inflation, while limiting as far as possible the cost to economic activity and preserving financial stability. Over the medium run, there is a need to sustainably rebuild monetary and fiscal buffers. Governments should reignite supply side growth drivers.

Powerful non-economic forces once again shaped economic developments over the past year. The emergence of the Omicron variant of Covid-19 dashed hopes of a quick and smooth global "pandexit". Meanwhile, the invasion of Ukraine triggered the largest European armed conflict in decades. First and foremost a humanitarian disaster, the war also had major repercussions for commodity and financial markets, and global supply chains.

For much of the year, growth was resilient. The global economy expanded strongly in 2021, although in the United States and China it fell short of expectations. As the review year progressed, the expansion lost some momentum, with supply constraints, Omicron and the war in Ukraine blowing headwinds.

Against this backdrop, global inflation rose to multi-decade highs. At first, higher inflation was seen as transitory, reflecting increased relative prices for a small number of pandemic-affected items. But it proved persistent, broadening over time. In response, central banks generally brought forward the timing and pace of policy tightening. Higher inflation and shifting expectations of the policy response led to bouts of financial market volatility, with financial conditions tightening substantially as the year progressed, albeit from an exceptionally easy state.

This combination of forces makes for a challenging outlook. The mix of high inflation, high and volatile commodity prices and significant geopolitical tensions bears an uncomfortable resemblance to past episodes of global stagflation. An uncertain growth outlook in China reinforces the downside risks. Unlike in the past, stagflation today would occur alongside heightened financial vulnerabilities, including stretched asset prices and high debt levels, which could magnify any growth slowdown.

In this environment, policymakers face several challenges. In the short term, the priority is to bring inflation down while limiting as far as possible the cost to economic activity and preserving financial stability.[1] At the same time, there is an imperative to rebuild monetary and fiscal buffers through a durable normalisation of policy settings. Recent economic developments further complicate this task. Fiscal policy in particular faces pressure to address higher living costs and, in some countries, increase military expenditures, while having to honour longer-term commitments to "green" the economy. These challenges put a premium on supply side reforms to promote sustainable growth.

This chapter first describes the key economic and financial developments over the past year. It then examines the looming stagflation risks. Finally, it elaborates on the policy challenges.

The year in retrospect

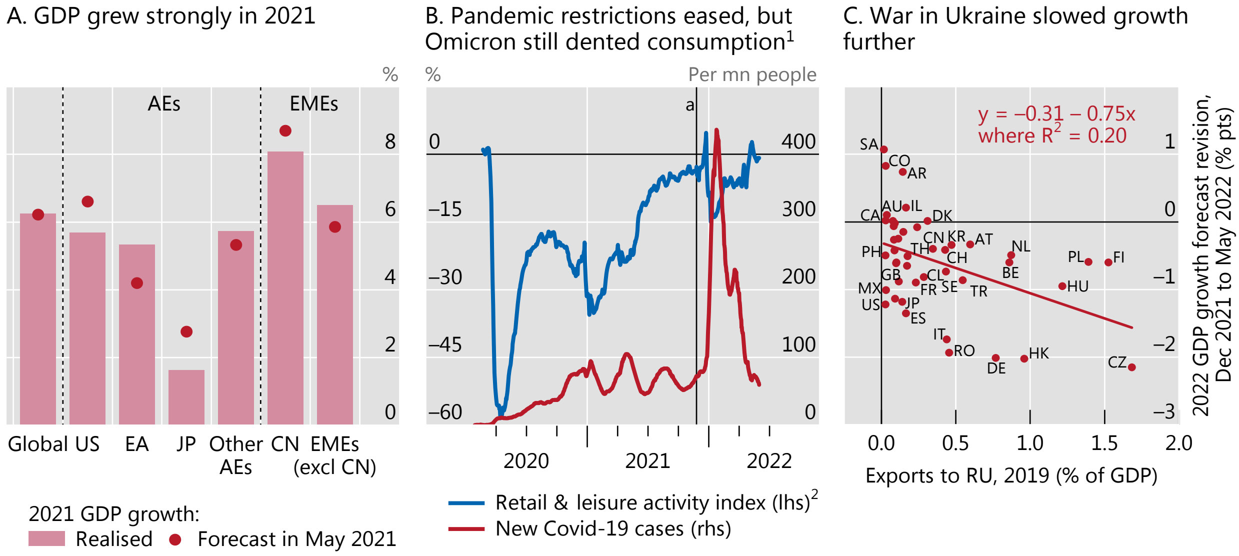
Global growth loses momentum as inflation returns

The year under review started well. Global GDP is estimated to have grown by 6.3% in 2021, its fastest rate in almost 50 years, and in line with expectations at the time of last year's Annual Economic Report (Graph 1.A).

The expansion in 2021 was broad-based. Japan aside, most advanced economies (AEs) grew strongly, bolstered by the easing of most remaining pandemic-related restrictions and very accommodative fiscal and monetary policy. Growth in emerging market economies (EMEs) (excluding China) varied, but as a group they expanded by 6.5%, supported by buoyant global goods trade, easy global financial conditions and, for commodity exporters, higher terms of trade.

Developments in China were less positive. Admittedly, GDP still grew by a solid 8.1% in 2021. However, this fell short of expectations. Regulatory interventions in the real estate and IT sectors weighed on activity. In addition, more frequent and broader lockdowns, in line with the authorities' "dynamic zero-Covid" policy, disrupted supply networks and undercut consumption.

Pandemic and war disrupted the expansion — Graph 1



[a] Covid-19 Omicron variant reported to World Health Organization.

[1] Global; seven-day moving averages. [2] Mobility trends relative to pre-Covid-19 period.

Sources: IMF; OECD; Consensus Economics; Google COVID-19 Community Mobility Reports; Our World in Data; national data; BIS.

The global expansion lost momentum as the review period progressed. Soaring infections once Omicron emerged in late 2021 cut consumer spending and, in some countries, labour supply (Graph 1.B). And, just as the expansion resumed, the war in Ukraine dealt a further blow. GDP growth forecasts for 2022 were marked down, particularly for countries more affected by the conflict (Graph 1.C).

In a striking break with the recent past, global inflation climbed to multi-decade highs. By early 2022, it exceeded central bank targets in almost all AEs, and had risen above 5% in more than three quarters of them (Graph 2.A). The share of EMEs with inflation above 5% was almost as high. Higher inflation was less prevalent in Asia. But even there, it generally rose above target as the year progressed, with the notable exception of China.

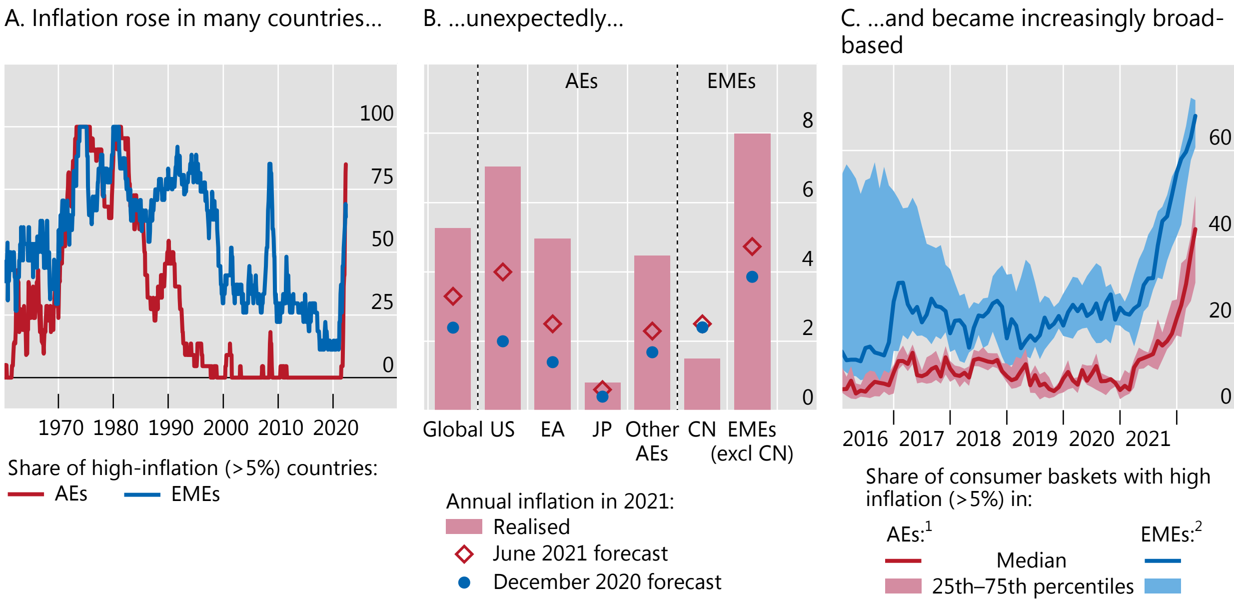
The flare-up in inflation came as a surprise to most observers. At the end of 2020, forecasts were generally projecting inflation at or below central bank targets (Graph 2.B). Even in mid-2021, by which time inflation had already started to rise, most forecasters underestimated the extent or persistence of the increase.[2] Contributing to the miss, the increase was initially concentrated in a narrow set of items, such as durable goods, food and energy. These price increases were widely interpreted as one-off or transitory relative price adjustments to pandemic-induced shifts in supply and demand. But inflation progressively broadened (Graph 2.C). By early 2022, growth in service prices, which tends to be more persistent, exceeded its pre-pandemic level in much of the world (Graph 3).

Higher inflation reflected a confluence of factors.

First, the recovery from the Covid recession has been unusually rapid, particularly in AEs (Graph 4.A). Massive fiscal and monetary policy support early in the pandemic bolstered household incomes despite large falls in GDP. This income boost – much of which was initially saved – paved the way for spending to bounce back as activity restrictions eased in 2021. However, some of this additional spending translated into

An unanticipated rise in global inflation

In per cent | Graph 2



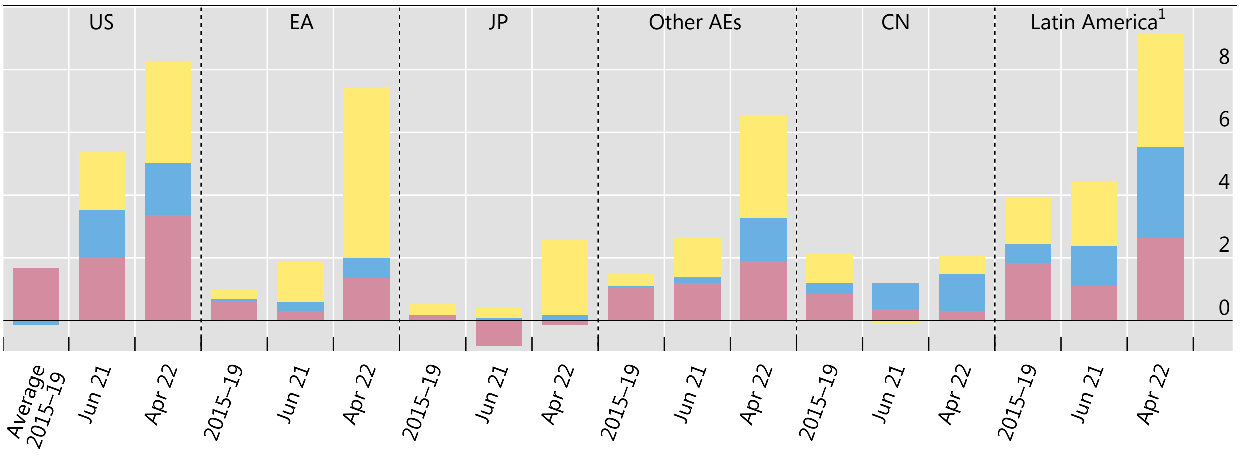
[1] AT, BE, CH, DE, DK, ES, FR, GB, IT, JP, NL, PT, SE and US. [2] BR, CL, CO, CZ, HU, KR, MX, PH, PL, RO and TR.

Sources: IMF; OECD; CEIC; Consensus Economics; national data; BIS.

Goods prices rose most, but price growth also increased for services

Contribution to year-on-year inflation; in per cent

Graph 3



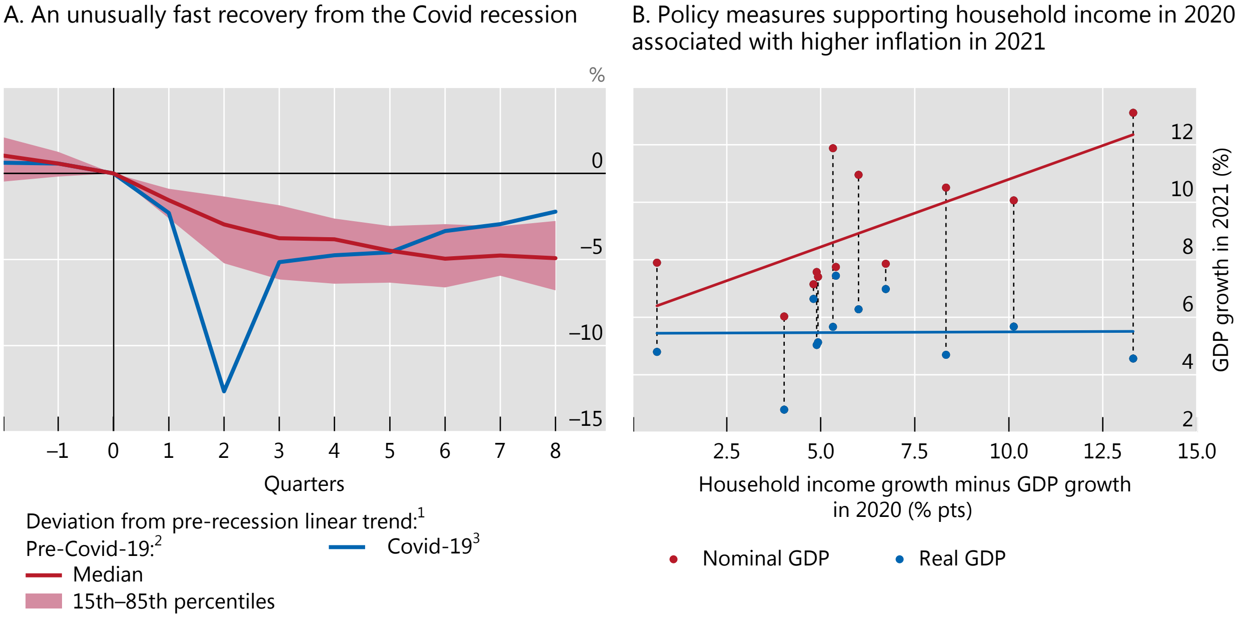
[1] CL, CO and MX.

Sources: OECD; Bloomberg; Datastream; national data; BIS.

higher inflation, so that the relationship between income support early in the pandemic and economic activity in 2021 was much more evident for nominal GDP than real output (Graph 4.B).[3] Meanwhile, policy measures such as furlough schemes and debt moratoriums helped prevent the feared wave of corporate bankruptcies.[4]

Causes of higher inflation: aggregate demand and income

Graph 4



[1] GDP trend calculated on the five years preceding the recession. Sample of seven AEs. [2] Cross-country median of 1985–2019 recessions. [3] GDP-weighted average of each country-specific Covid-19 recession.

Sources: IMF; OECD; BIS.

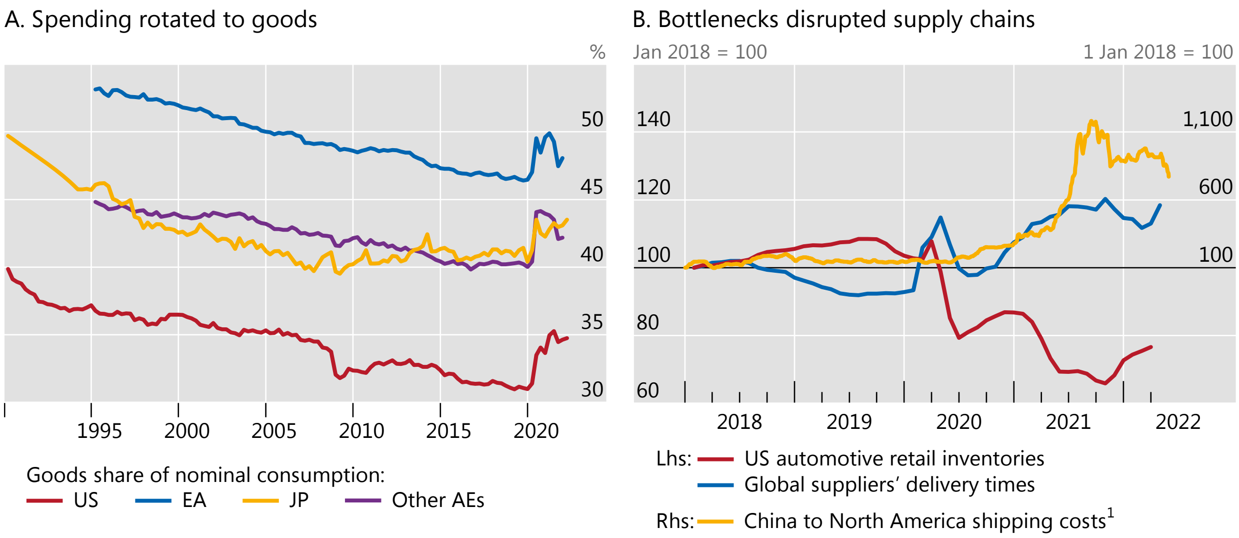
Second, the pandemic-induced rotation of aggregate demand to goods from services, especially contact-intensive ones, proved surprisingly persistent. Little demand rotated back, even after most containment measures were lifted (Graph 5.A). Strong price increases by firms operating at full capacity in industries facing high demand were not matched by slower price growth elsewhere.[5] As a result, inflation rose even as output remained below its pre-pandemic trend and labour markets pointed to spare capacity.

Third, supply failed to keep up with surging demand. In particular, global value chains came under pressure.[6] In some cases, the pressure reflected disruptions due to natural disasters, geopolitical conflicts and lockdowns; in others, simply the strength of demand. Thus, bottlenecks emerged in a number of areas, including container shipping and semiconductors, leading to sharp price increases (Graph 5.B).[7] Since many bottlenecks affected goods and services located "upstream", ie near the start of production networks, the supply constraints had large spillovers across industries and countries. This caused long delivery delays and left many retailers short of inventory.

Supply was especially tight in energy and other commodity markets, triggering major price increases and higher volatility (Graph 6.A, Box A). In this case, a legacy of low investment by resource producers further restricted supply (Graph 6.B). Partly as a result, the supply response of marginal producers, such as those of shale oil, fell short of previous ones, which had helped to moderate commodity price shifts in the 2010s (Graph 6.C). The war in Ukraine further disrupted the global supply of products such as wheat, oil, gas, nickel, palladium and fertilisers.

In several EMEs, central banks responded quickly to rising inflation. In Latin America, many had already raised policy rates several times by the end of 2021 (Graph 7.A). In Asia, where inflation was generally lower, policy tightening occurred later and more gradually. Still, by early 2022 most EME central banks had started to remove accommodation. The People's Bank of China was an important exception: it eased as the economy softened and inflation remained subdued (Graph 7.B).

Causes of higher inflation: demand composition and supply constraints — Graph 5



[1] Seven-day moving average.

Sources: Federal Reserve Bank of St Louis, FRED; IMF; OECD; Datastream; IHS Markit; national data; BIS.

Box A

Rising commodity prices: are we set for a repeat of the 1970s?

The past year has seen a significant rise in global inflation alongside higher commodity prices. This combination recalls the experience of the 1970s, particularly the aftermath of oil crises in 1973 and 1979. Those crises contributed to higher inflation and to a slowdown in global growth, which declined from an average of 5.5% in the decade leading up to the 1973 oil crisis to 2.5% in the following one. There are several reasons to expect recent commodity price rises to be less disruptive than those of the 1970s: recent price rises are proportionally smaller, albeit spread across a broader range of commodities, commodity supply has so far held up better, the global economy has become vastly more efficient in its use of many commodities, and the inflationary backdrop is more benign. That said, adverse outcomes are still possible if policymakers repeat the mistakes of the 1970s.

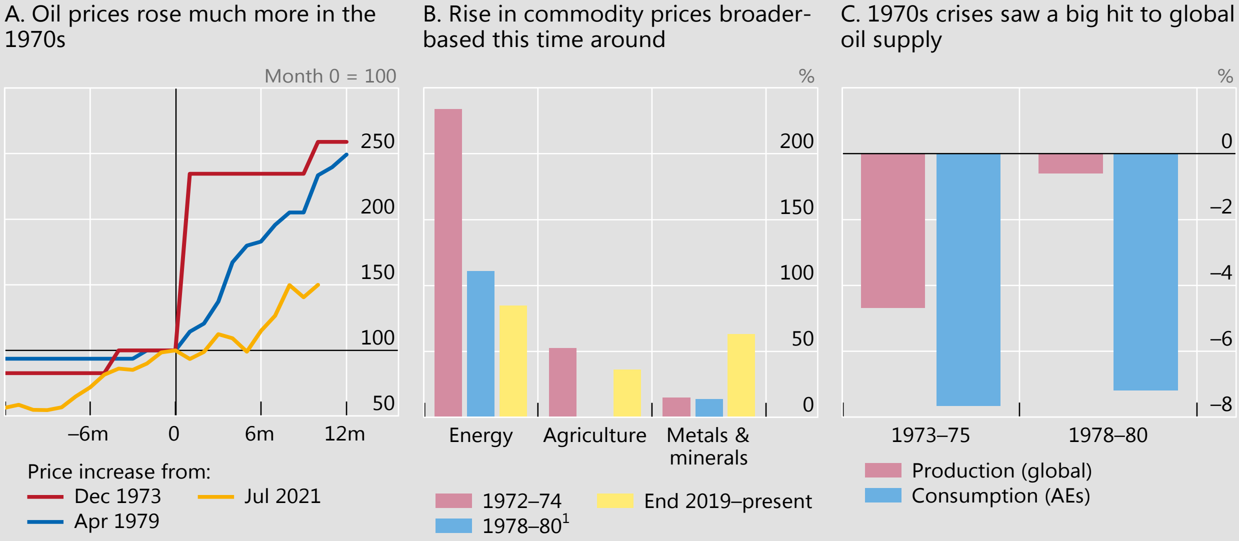
Recent commodity market developments differ from those of the 1970s in several respects. The 1970s crises were concentrated in the oil market. In the 1973 crisis, oil prices more than doubled in the space of a month (Graph A1.A). Prices rose to a similar extent in the 1979 crisis, albeit more gradually. Recent oil price increases have been modest in comparison. Oil prices have increased by around 50% since the middle of 2021, although they briefly rose more after the start of the war in Ukraine in late February.[1] Taking a longer-term perspective, oil prices today are still within the range of long-term averages, being at roughly the same level in nominal (US dollar) terms as they were in mid-2014, and about 20% lower in real terms. In contrast, the 1970s crises took oil prices to historic highs.

But while oil prices have so far increased by less than during the 1970s crises, a broader range of commodities has experienced price increases. The prices of non-oil energy, some agricultural goods, fertilisers and metals have all risen significantly over the past year, to be well above their pre-pandemic levels (Graph A1.B). Increases in European natural gas prices, which rose almost fourfold between the middle of 2021 and early 2022 and eight times from pre-pandemic levels, were particularly notable. In contrast, the 1970s crises were more concentrated in oil and, in the 1973 case, agricultural products.

Commodity supply disruptions have played a smaller role in recent price increases than in the 1970s. Global oil production dropped by around 5% around the 1973 oil crisis (Graph A1.C). The decline in oil consumption in AEs was even larger, at around 8%, due in part to embargos. Global oil production fell by less around the 1979 crisis, although oil consumption in AEs again decreased substantially. In contrast, the rise in commodity prices over the past year has been accompanied by a modest rise in the production of many commodities, although not oil. That said, supply disruptions could intensify over the coming year. The war in Ukraine will lower global production of agricultural commodities such as wheat and maize, as well as fertilisers.[2] Meanwhile, sanctions on Russian oil and gas would represent an effective reduction in the

The current commodity price rise vs the 1970s: how do they compare?

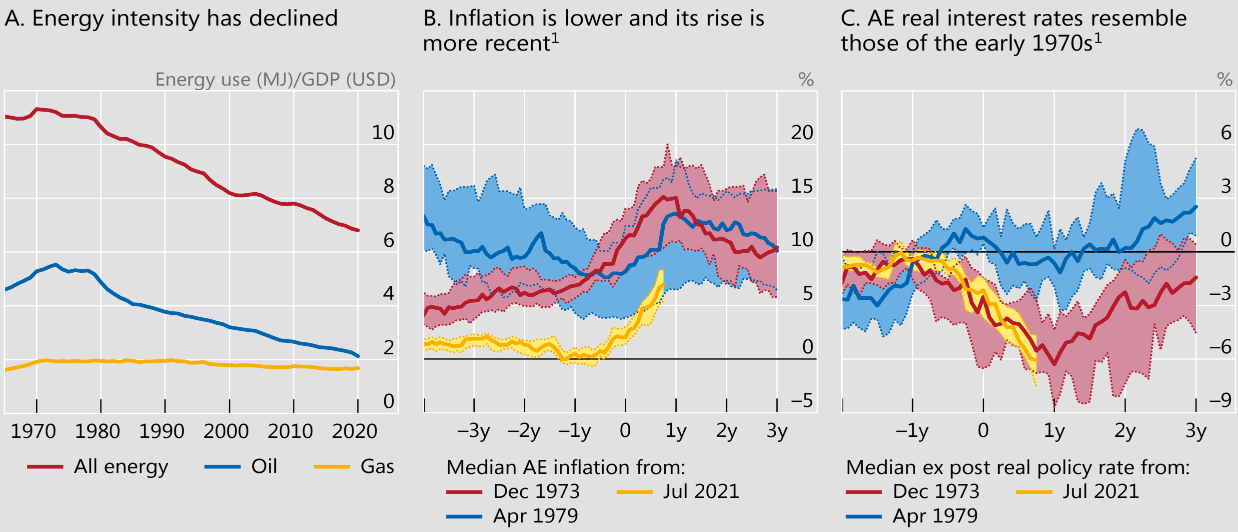
Graph A1



[1] Value for "agriculture" is 0.25%.

Sources: Federal Reserve Bank of St Louis, FRED; World Bank; BP; Datastream; national sources; BIS.

Rising commodity prices: will this time be different? Graph A2



MJ = megajoule.

[1] Shaded areas indicate 20th–80th percentiles.

Sources: World Bank; BP; Datastream; Global Financial Data; national data; BIS.

supply of these products, where Russia accounted for around 12% and 17%, respectively, of global production in recent years.

Aside from differences in commodity market behaviour, there are several reasons to think that the current episode could play out differently to those of the 1970s. Higher energy prices, in particular, could matter less for growth today than in the past. The energy intensity of GDP – the amount of energy required to produce a given amount of goods and services – has fallen by around 40% since the late 1970s (Graph A2.A). The reduction has been most striking for oil, for which consumption has more than halved relative to GDP. To be sure, some of this reflects a shift in energy use from oil to other fuels, such as gas, whose prices have also risen recently. But even for gas, total consumption per unit of GDP is lower now than in the late 1970s.

The inflationary environment today is also arguably more benign. Although global inflation has risen significantly since the start of 2021, this follows several years of low inflation (Graph A2.B). In contrast, the 1973 crisis took place against a backdrop of several years of steadily rising global inflation and signs that inflation expectations were de-anchoring.[3] Inflation was also generally high in the lead-up to the 1979 oil crisis, albeit with substantial cross-country dispersion. The high-inflation environment of the 1970s may have contributed to the large "spillovers" of rising oil prices to the prices of other goods and services (Chapter II).

The consequences of recent commodity price increases will depend on how policymakers respond. One reason to expect more favourable outcomes is that monetary policy frameworks are very different. The 1973 crisis closely followed the collapse of the Bretton Woods managed exchange rate regime. At that time, the goals and even instruments of monetary policy were poorly defined in many countries. Central banks today have much clearer and more robust institutional frameworks. Even so, the path of real interest rates over the past year, at least in AEs, bears a striking resemblance to that in the 1970s, with large declines in real interest rates in the lead-up to the oil price shock in both episodes (Graph A2.C). In contrast, in the 1979 crisis real interest rates were more stable in the face of higher oil prices and then eventually increased substantially as central banks sought to bring inflation under control.

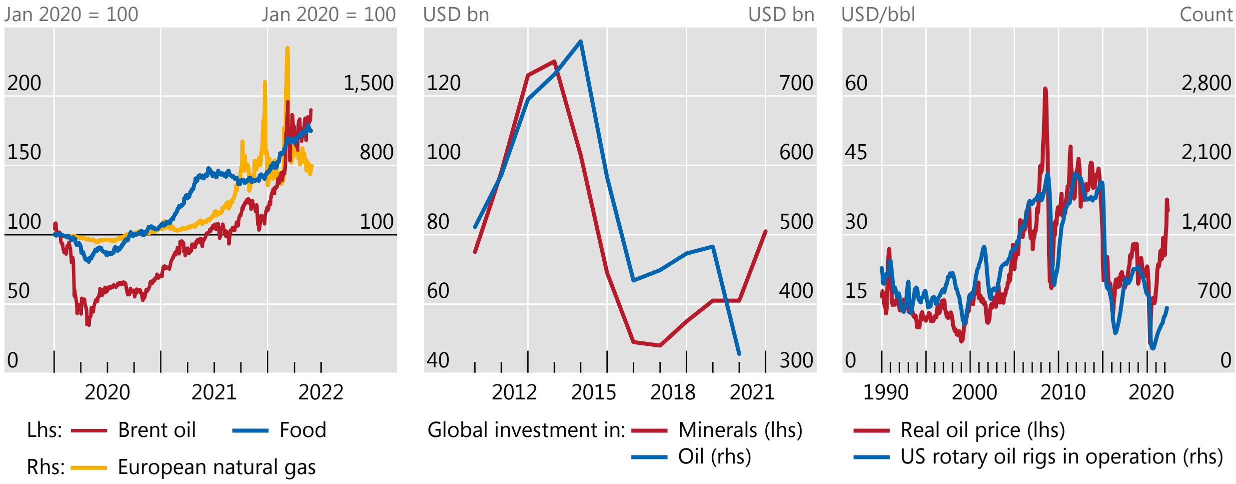
The conduct of fiscal policy will also matter. In AEs, many governments sought to cushion the blow to incomes from the 1973 oil crisis with expansionary fiscal measures.[4] The resulting increase in aggregate demand added to inflationary pressures. In contrast, the fiscal responses to the 1979 oil crisis were generally less expansionary. The backdrop to the current crisis is quite different, with budget deficits projected to contract in most jurisdictions as governments withdraw stimulus deployed at the height of the Covid-19 pandemic. That said, a number of governments have announced tax cuts or expanded subsidies in response to recent commodity price rises, as occurred following the 1973 oil crisis.

[1] While the increase in oil prices since their trough in April 2020 has been much larger, those low levels followed an unprecedented price decline in the early stages of the pandemic. [2] See Food and Agriculture Organization of the United Nations (2022). [3] See Reis (2021). [4] See Black (1985) and Roubini and Sachs (1989).

Commodity prices and supply

Graph 6

A. Commodity prices soared due to strong demand… B. …a legacy of low investment… C. …and a sluggish supply response



Sources: International Energy Agency; Bloomberg; PwC; national data; BIS.

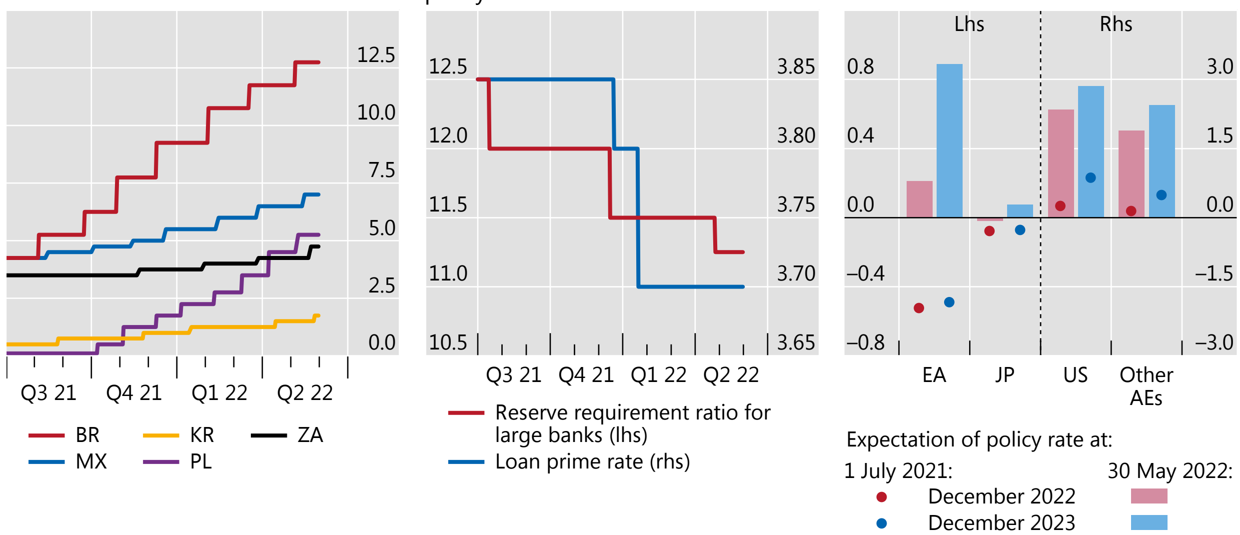
In AEs, central banks responded more slowly. Initially, many attempted to "look through" seemingly transitory higher inflation. But as the review year progressed, central banks wound back their forward guidance, signalling an earlier start of policy normalisation (Graph 7.C). In the United States, the Federal Reserve shifted in December towards a quicker tightening pace and had raised the federal funds rate by 75 basis points by the end of the review period. A number of small open economy central banks also hiked interest rates several times by early 2022. In the euro area,

Monetary policy tightened in most economies, with China an exception

In per cent

Graph 7

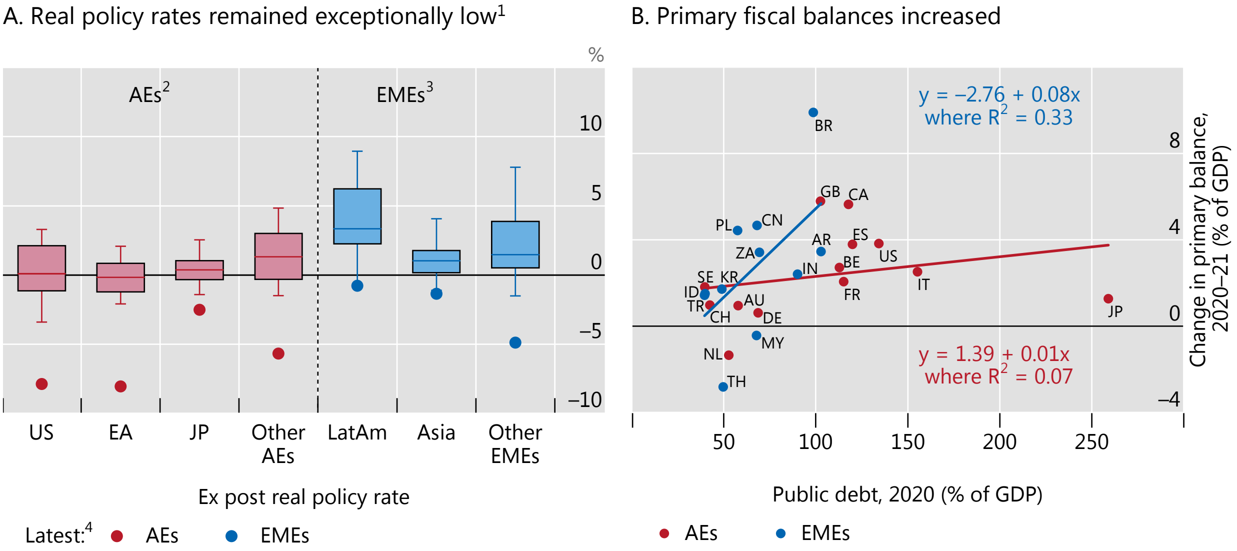
A. EME central banks were the first to raise interest rates B. More accommodative monetary policy in China C. Expectations of future AE policy rates increased



Sources: Bloomberg; Datastream; national data; BIS.

The monetary and fiscal stance

Graph 8



[1] Box plots show medians, interquartile ranges and fifth–95th percentiles. [2] Data starting in 1990. [3] BR, CN, HK, ID, IN, KR, MX, MY, PL, TH and ZA. Data starting in 2000 (subject to data availability). [4] See technical annex for details.

Sources: IMF; OECD; national data; BIS.

market participants brought forward their expectations of the timing of interest rate increases, while the ECB gradually adjusted its guidance to raise the possibility of an earlier policy tightening. The Bank of Japan remained an exception, maintaining its highly accommodative stance.

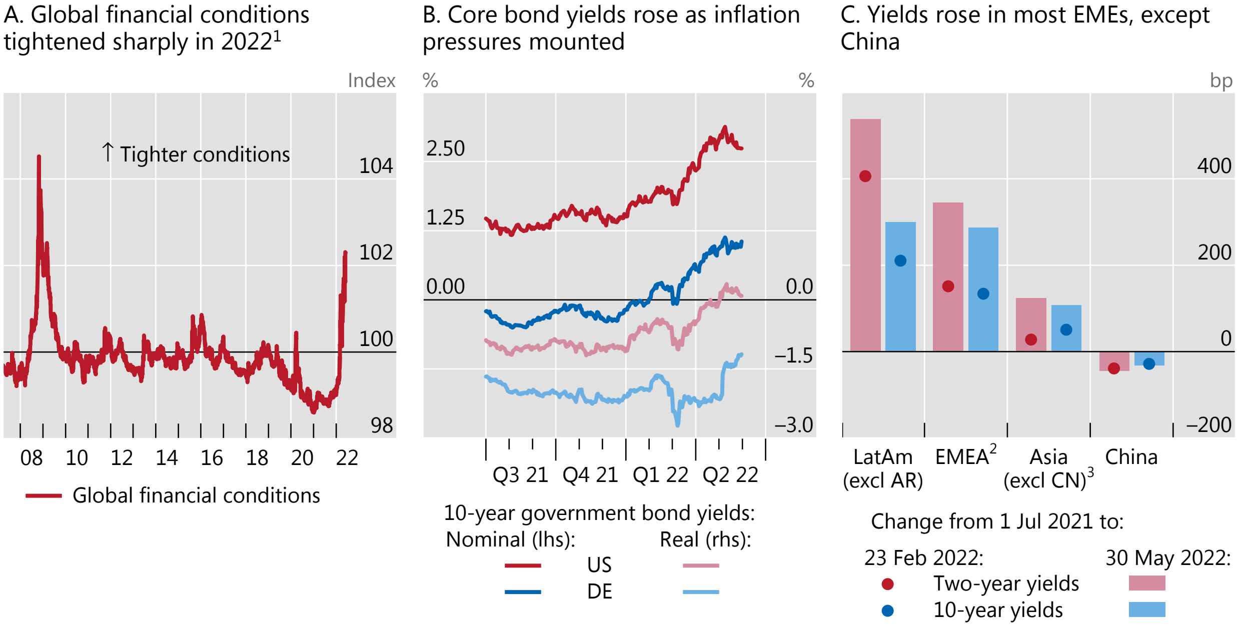
Nominal policy rates generally increased by less than near-term inflation. As a result, real ex post policy rates – ie adjusted for realised inflation – actually fell in most countries, from levels that were already exceptionally low. In most AEs, at the time of writing, real rates are 1–6 percentage points below their historical range over the past three decades (Graph 8.A). Real policy rates have generally been somewhat higher in EMEs, but remain negative in most.

Fiscal deficits declined in most countries. Improving economic conditions allowed governments to wind back some of the fiscal stimulus deployed at the height of the pandemic. In EMEs, fiscal constraints loomed large and countries with higher debt levels generally implemented larger fiscal consolidations (Graph 8.B). While fiscal deficits generally shrank in AEs, governments in the United States and Europe laid the groundwork for large infrastructure programmes in the coming years.

Inflation and war shape financial conditions

Higher inflation and the outbreak of war in Ukraine also left an imprint on financial markets. Financial conditions tightened sharply during the review period, particularly from the start of 2022, as asset prices responded to the prospect of rising inflation and the resulting anticipated monetary policy tightening (Graph 9.A). The extent of the tightening varied across countries and asset classes, reflecting their different exposures to economic and geopolitical developments.

The consequences of the shifting macroeconomic conditions were first evident in sovereign bonds. In the core bond markets, nominal yields rose sharply in October 2021, particularly at shorter maturities. Long-term yields followed from December as the Federal Reserve flagged an earlier and faster policy tightening, Financial conditions tightened as government bond yields rose globally — Graph 9



[1] A value of 100 indicates average conditions. [2] CZ, HU, IL, PL and ZA. [3] ID, IN, MY, PH and TH.

Sources: Bloomberg; Goldman Sachs Global Investment Research as of 31 May 2022; BIS.

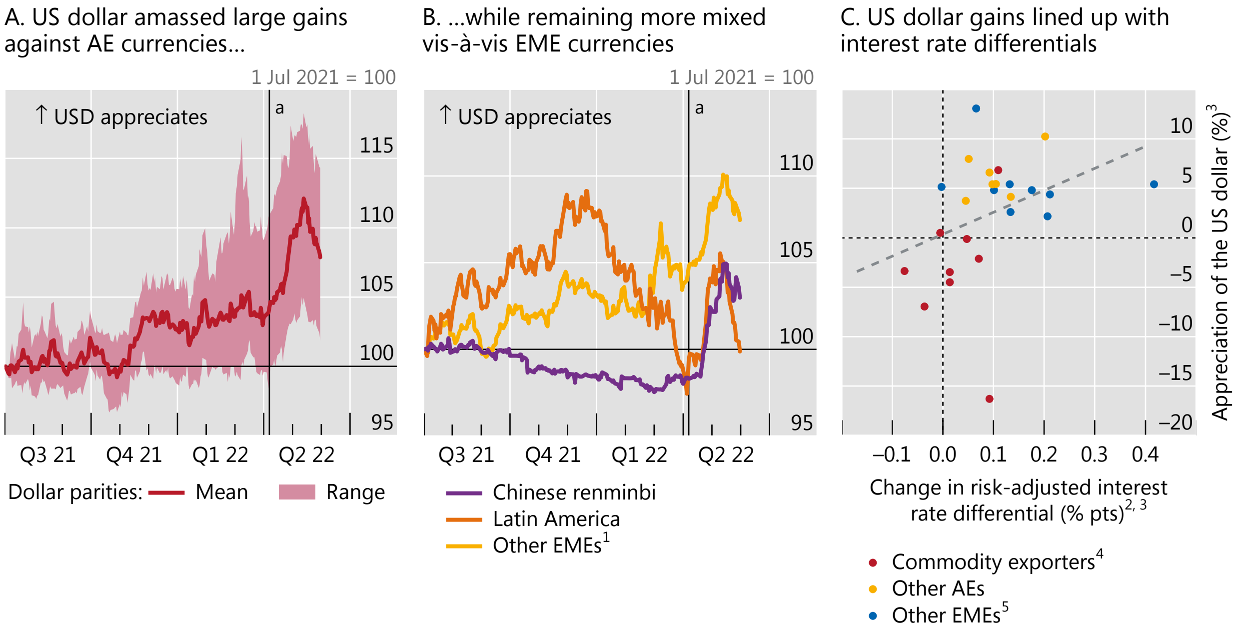
before moving sharply higher after the start of the war in Ukraine (Graph 9.B). The rise in US yields initially reflected higher inflation compensation, particularly at shorter maturities. But real long-term yields also increased materially after the start of the war. Indeed, in May the yield on 10-year Treasury Inflation-Protected Securities became positive for the first time since the start of the pandemic (light red line). In the euro area, German real yields remained deeply in negative territory (light blue line), despite a jump in May as the ECB flagged an earlier rise in policy rates. Over the entire period, however, the rise in German yields was due largely to increased inflation compensation.

Shifts in the shape of the US yield curve amid faster than anticipated monetary tightening raised concerns about the economic outlook. Starting in October, the US yield curve flattened as short-term yields rose by more than long-term ones. In March, it briefly inverted, which is often seen as a signal of an imminent recession. In the event, the inversion was short-lived and reversed sharply in early April. Such a flattening was not observed in the euro area and Japan, reflecting their slower pace of monetary tightening.

In EMEs, sovereign yields also increased alongside inflation. Initially, they rose more in Latin America, where inflationary pressures were strongest and many central banks had already started tightening policy early in 2021 (Graph 9.C). The increase of sovereign yields in eastern Europe accelerated after the outbreak of war in Ukraine, reflecting these countries' greater exposures to the conflict. Asian economies generally saw smaller sovereign yield increases, as inflation was slower to gain momentum in the region. In China, yields declined, as policymakers wrestled with the fallout of a troubled real estate sector and renewed Covid outbreaks.

Tighter US financial conditions spilled over globally through an appreciation of the US dollar. The appreciation proceeded in two steps. The first, lasting from late 2021 to March 2022, was gradual, reflecting evolving inflationary concerns and expectations that monetary tightening would proceed more quickly in the United States than in other AEs (Graph 10.A). EME exchange rate movements were more

The US dollar appreciated as Federal Reserve tightening gained momentum Graph 10



[a] Release of minutes of the March 2022 FOMC meeting.

[1] CZ, HU, ID, IL, IN, KR, MY, PH, PL, TH and ZA. [2] An increase in the differential would typically make the US dollar more attractive vis-à-vis the corresponding currency. See technical annex for details. [3] Changes over 3 January–27 May 2022. [4] AUD, BRL, CAD, CLP, COP, MXN, NOK, PEN and ZAR. [5] CNY, CZK, HUF, IDR, INR, KRW, MYR, PHP and PLN.

Sources: Bloomberg; JPMorgan Chase; BIS.

varied. Commodity exporters, particularly in Latin America, even saw their exchange rates appreciate on the back of widening interest rate differentials and rising commodity prices (Graph 10.B). The renminbi also strengthened gradually, supported by a large current account surplus and portfolio inflows.

From April, the pace of US dollar appreciation increased sharply, before retracing somewhat in late May. The appreciation coincided with the large upward shift in the US yield curve, the reversal with renewed concerns about the global growth outlook. Overall, since the beginning of 2022 the US dollar appreciated most against the currencies of non-commodity exporters that were less advanced in their tightening cycles, as reflected in the expected changes in risk-adjusted interest rate differentials (Graph 10.C). Also in the second quarter, gold prices gave up the modest gains amassed earlier in the year, while cryptocurrencies, particularly ethereum and bitcoin, plummeted to their lowest levels since mid-2021. Some stablecoins, such as tether, deviated significantly from their benchmarks, while others broke down completely in a manner resembling the collapse of traditional exchange rate pegs.[8] Capital outflows from most EMEs, however, were moderate, signalling the surprising resilience of investor sentiment towards this asset class in the face of tighter global financial conditions.

Corporate credit conditions tightened significantly as the year progressed. Relative to their distribution since the Great Financial Crisis (GFC), investment grade credit spreads saw the sharpest increases, although spreads in all rating categories rose from historical lows to levels exceeding their post-GFC medians (Graph 11.A). The relatively muted rise in high-yield credit spreads was partly due to rising investor demand for floating rate debt – more prevalent in the high-yield segment – at a time of higher expected future policy rates. It may also have reflected falling liquidity

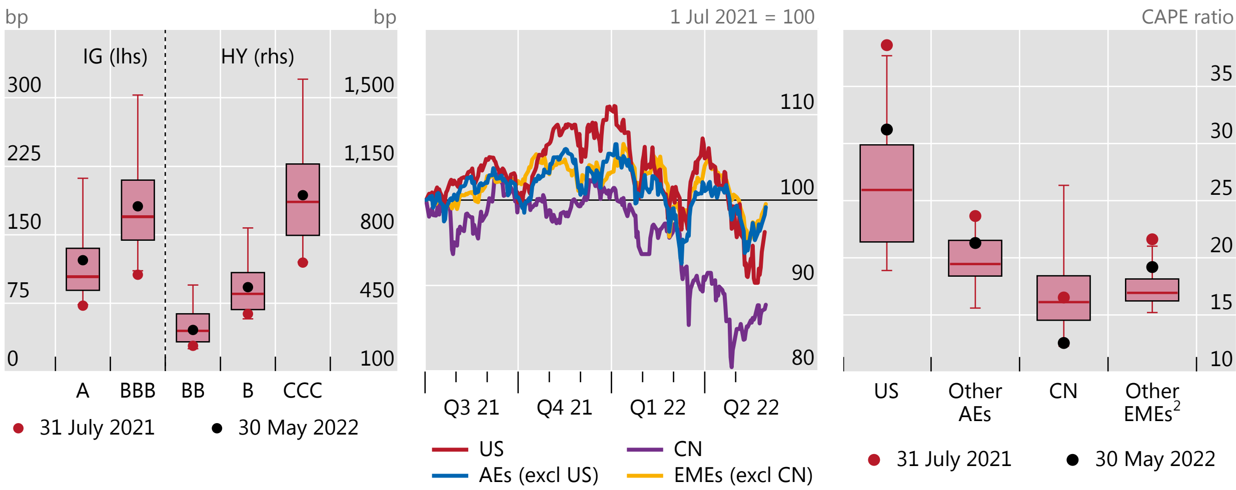
Risky assets saw a large correction in valuations, and corporate financing tightened

Graph 11

A. Corporate credit spreads widened substantially[1]

B. Stock markets dived in 2022, amid bouts of heightened volatility…

C. …resulting in large falls in equity valuations[1]



CAPE = cyclically adjusted price-to-earnings; HY = high-yield; IG = investment grade.

[1] Box plots show medians, interquartile ranges and fifth–95th percentiles; data starting in 2010. [2] BR, HK, IL, IN, KR, MX, PL, SG, TR and ZA.

Sources: IMF; Barclays; Bloomberg; Datastream; ICE BofAML; BIS.

in high-yield corporate debt markets, particularly in the euro area, which delayed the full repricing of riskier debt.

Equity markets saw large fluctuations amid broad sectoral divergences. Stock prices generally rose in the first half of the review period, albeit with bouts of volatility as higher inflation and Omicron rattled investor sentiment (Graph 11.B). They then fell significantly in 2022 in the wake of the Federal Reserve's tightening shift and the expectation that other central banks would follow suit, as well as the outbreak of the war. In most regions, valuations declined, although they generally remained above their post-GFC medians (Graph 11.C).

Chinese equities were an important exception. They drifted down from early 2022, as problems in the real estate sector lingered and Covid-related lockdowns intensified (Graph 11.B). The rout accelerated after the beginning of the war, with Chinese assets – both stocks and bonds – seeing large outflows, leaving valuations at post-GFC troughs (Graph 11.C).

Stagflation: how high are the risks?

Although global growth was generally resilient over the review period, downside risks loom large. To a great extent, this reflects the unique nature of the Covid recession and subsequent expansion, which has led to higher inflationary pressures alongside elevated financial vulnerabilities, notably high indebtedness against a backdrop of surging house prices. This combination is historically unprecedented. Prior to the mid-1980s, recessions were generally preceded by high inflation and the associated monetary tightening while the financial system was largely repressed. Since then, Covid aside, recessions have typically followed financial cycle peaks, with inflation remaining subdued during expansions and hence calling for relatively little monetary policy tightening.

The absence of historical parallels makes for a highly uncertain outlook. At a minimum, a spell of below-trend growth will be required to return inflation to acceptable levels. But a modest slowdown may not be enough. Lowering inflation could involve significant output costs, as after the "Great Inflation" of the 1970s. Even then, inflation may not fall quickly, given the intensity of recent price pressures. In a worst case scenario, the global economy could be set for a period of stagflation, involving both low growth, if not an outright recession, and high inflation.

How could such a stagflationary situation arise? The entrenchment of recent high inflationary outcomes, reinforced by rising commodity prices, would be a natural starting point. High commodity prices could also weigh on global growth, as would a significant slowdown in the Chinese economy. Financial stress could magnify the growth slowdown. EMEs are especially exposed.

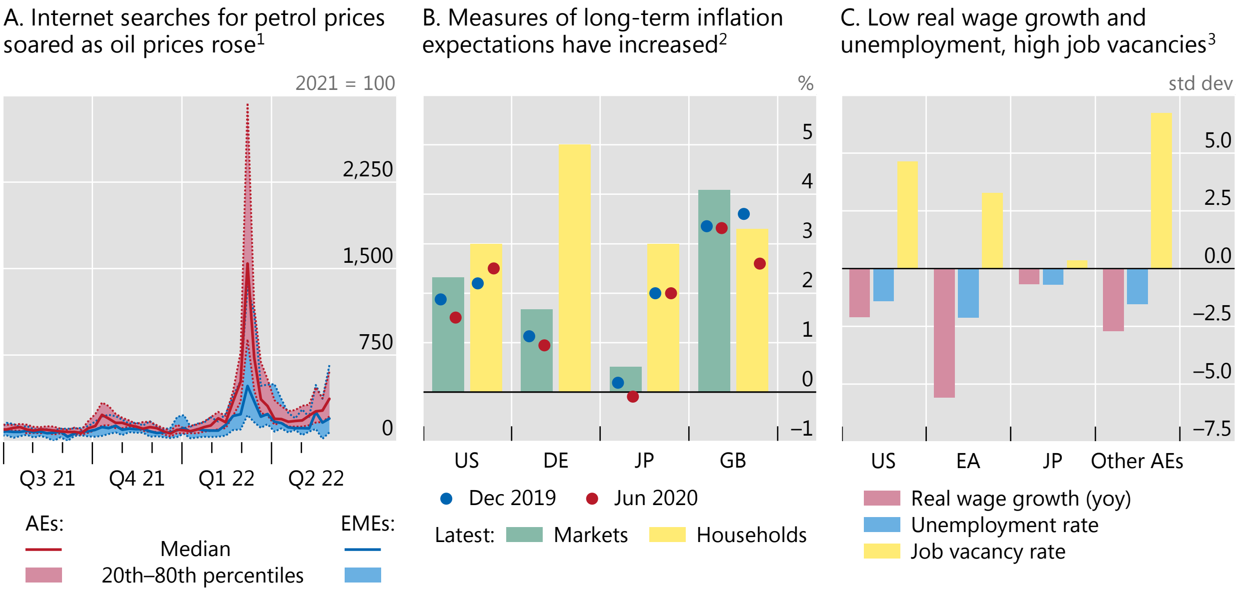
A new inflation era?

Inflation regimes have self-reinforcing properties (Chapter II). Just as low inflation helped to moderate wage and price rises before the pandemic, so recent high inflation outcomes may lead to behavioural changes that could entrench it. Such a shift is most likely if an inflation rise is large and persistent enough – ie salient – to leave a large imprint on the lives of workers and firms, and if they have sufficient bargaining and pricing power to trigger a wage-price spiral.

There are several indications that recent inflation increases have been salient. For instance, internet searches for the price of petrol surged in early March (Graph 12.A). And measures of inflation expectations, for both households and financial market participants, have started to increase (Graph 12.B).

At the same time, the conditions for faster wage and price growth look to be in place. Real wages grew unusually slowly over the past year, and declined in some

High inflation could become entrenched | Graph 12



[1] Based on Google searches for country-specific expressions for "petrol prices". [2] For markets, five-year forward break-even inflation rate. For households, median response to survey question on inflation expectations at five-year horizon. Household data for DE start in October 2020. [3] Standard deviation of latest observation (Q4 2021 or Q1 2022) from 2000–19 mean.

Sources: Deutsche Bundesbank; Bank of Japan; Bank of England; OECD; Bloomberg; Datastream; Google Trends; University of Michigan Surveys of Consumers; national data; BIS.

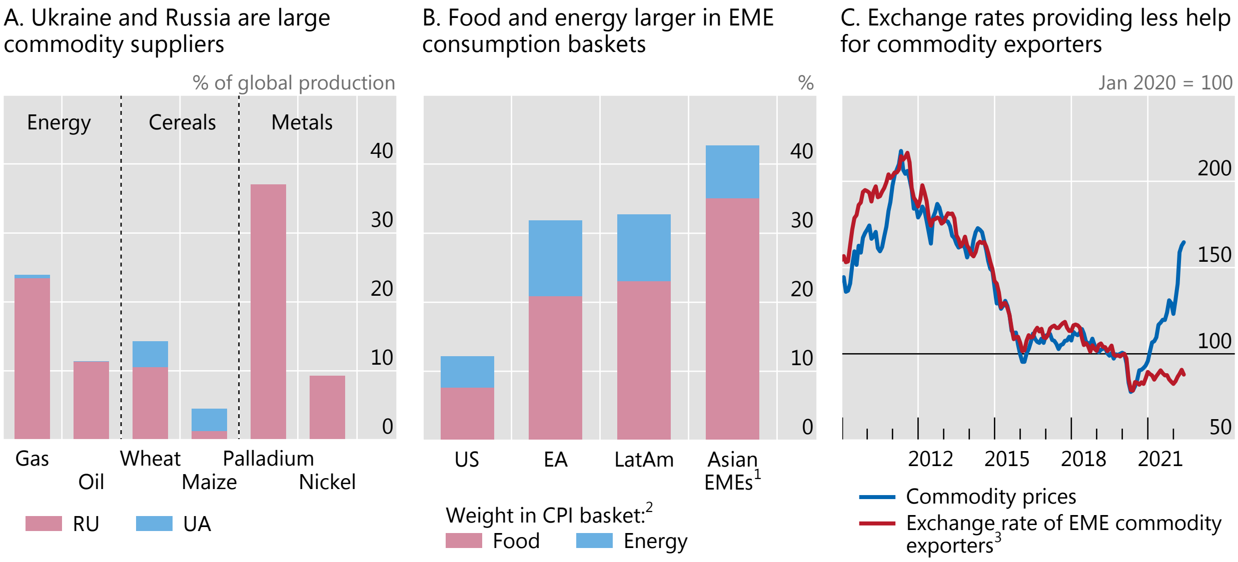
jurisdictions, even as labour market conditions were remarkably tight, with job vacancy rates well above their historical averages and unemployment rates low (Graph 12.C). In part, this reflects the fact that wages tend to be negotiated infrequently, and so naturally take time to respond when inflation increases unexpectedly. As existing wage agreements expire, workers are likely to seek larger wage rises. In some countries they have already secured wage indexation clauses to guard against future inflation surprises.[9] Meanwhile, the recent broadening of inflation pressures suggests that many firms have greater pricing power than they had pre-pandemic.

The war in Ukraine

The war in Ukraine adds to the inflationary pressures. The primary channel is through higher commodity prices, particularly for oil, gas, agricultural products and fertilisers, of which Russia and Ukraine are significant producers (Graph 13.A). Some of these price rises – eg for oil and wheat – will feed directly into inflation. EMEs will be hit harder than AEs, given the typically larger share of food and energy in consumption baskets (Graph 13.B). Exchange rate appreciations may reduce imported price pressures for commodity-exporting EMEs, although this relationship appears to have weakened since the start of the pandemic (Graph 13.C). Other price rises, eg for metals, will raise firms' production costs and could intensify price pressures through global value chains.

The net effect of these factors could be material, particularly as inflation is already high. Estimates of the effect of commodity price increases across a broad panel of countries indicate that a 30% increase in oil prices, combined with a 10% rise in agricultural prices – roughly in line with those seen since the start of the year – has historically been associated with a 1 percentage point increase in inflation in the following year (Graph 14.A).[10] For European countries, where gas prices have surged even more than oil prices, the effects could be larger.

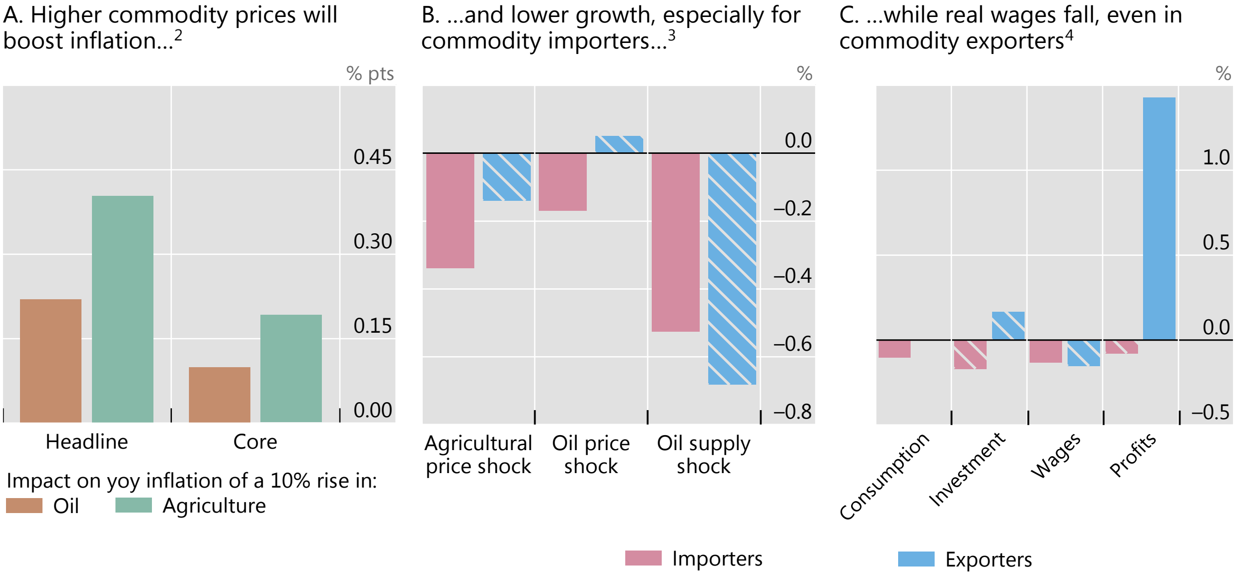
Commodity prices and inflation | Graph 13



[1] KR, IN and PH. [2] PCE for US. [3] BR, CL, CO, MX and ZA.

Sources: International Energy Agency; OECD; UN Food and Agriculture Organization; US Geological Survey; Bloomberg; Datastream; national data; BIS.

Implications of higher commodity prices for inflation and growth[1] Graph 14



[1] Impulse responses from structural vector autoregression models. Diagonal patterns indicate values that are not statistically significant at the one standard deviation confidence level. See technical annex for details. [2] Responses 12 months after the initial shock. [3] Responses of GDP to a shock that raises commodity prices by 10%, eight quarters after the initial shock. [4] Responses to an oil price shock that raises oil prices by 10%, eight quarters after the initial shock.

Sources: Igan et al (2022); OECD; Datastream; national data; BIS.

Commodity market disruptions will also weigh on growth (Graph 14.B). By raising firms' production costs, higher commodity prices effectively lower global aggregate supply. Although commodity exporters will benefit from higher export revenues, largely in the form of higher corporate profits, the growth boost could be smaller than usual if tighter financial conditions and expectations that the rise in commodity prices will be temporary deter firms from investing to boost capacity (Graph 14.C).[11, 12] Meanwhile, for commodity importers, the terms-of-trade loss will further compress domestic incomes and aggregate demand. The hit to growth could be even larger if higher commodity prices are accompanied by a cut to global commodity output and rationing, as occurred in the 1970s.

This speaks to possible broader consequences of the war, beyond its effect on commodity markets. Admittedly, the hit to trade flows is relatively small on a global scale. But the conflict has created an environment of higher uncertainty and political risk, which is historically associated with lower business investment.[13] And over the longer term, the new geopolitical landscape could see real and financial fragmentation, including through a reorganisation of global supply chains.

Slower growth in China

Developments in China could be a further source of global stagflationary pressure. On the one hand, the country has accounted for a sizeable share of global growth – around one quarter – over the past two decades. In addition, it has been a major source of external demand for the rest of the world, notably for raw materials. On the other hand, China's entry into the global trading system exerted persistent disinflationary pressures, particularly in AEs, even as its domestic demand pushed up commodity prices.[14] There are signs, however, that some of these influences could now be waning.

Some of the factors contributing to China's growth slowdown are structural, and hence likely to be long-lasting. China's working age population, which peaked in the early 2010s, will decline further in the coming years. Meanwhile, the potential for further productivity gains from incorporating pre-existing technology and reallocating labour to higher-productivity activities has diminished. The slowdown in labour productivity growth as China has approached the technology frontier is broadly comparable with those of Japan and Korea in previous decades (Graph 15.A). This suggests that a return to very high productivity growth rates is unlikely.

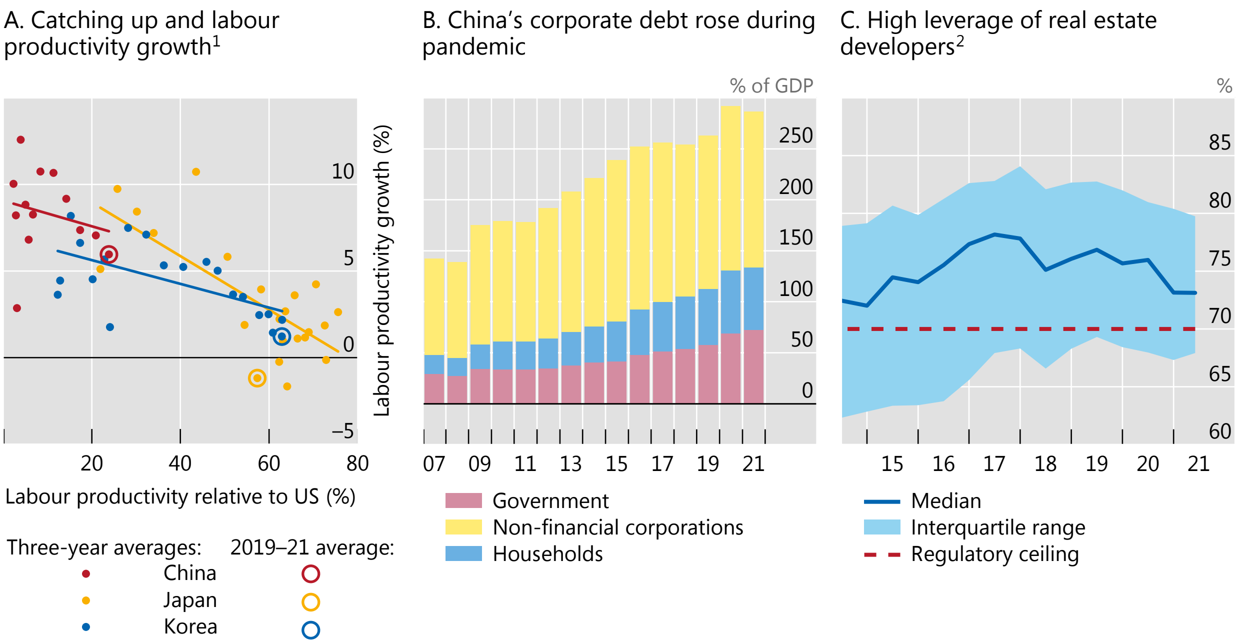
A prolonged downturn in the financial cycle would exert a further drag on growth. Against a backdrop of high debt levels, the influence of financial factors was already evident in the year under review. In response to the further build-up of corporate debt during the pandemic, and the continued high leverage of property developers, Chinese authorities introduced several measures to reduce real estate vulnerabilities in the second half of 2021 (Graphs 15.B and 15.C). These cut developers' ability to borrow, leading some to delay debt payments and shed assets, and curtailed mortgage lending to households. Such measures enhance the sustainability of growth over the longer run but dampen growth in the near term (Box B). Indeed, the relaxation of some measures in early 2022 highlights the authorities' difficult balancing act.

Pandemic-related developments exacerbate near-term headwinds. Local lockdowns and other measures to enforce the authorities' strict Covid policy could further disrupt production networks, both within China and with trading partners.[15] The fight against the virus is far from over.

Macro-financial vulnerabilities

China is far from the only country with significant macro-financial vulnerabilities. More than a decade of exceptionally accommodative financial conditions, reinforced

China: structural slowdown and strains from the real estate sector — Graph 15



[1] For JP, data start in 1956; for KR, 1962; for CN, 1983. [2] Liability-to-asset ratio (excluding advance receipts); top 50 listed developers by total assets.

Sources: The Conference Board Total Economy Database™, April 2022; Wind; national data; BIS.

by the policy response to the pandemic, has left firms and households in many countries highly indebted and has contributed to elevated asset prices, especially for property. Unusually, these vulnerabilities did not decline materially during the Covid recession. Indeed, in most countries private debt levels, particularly for the non-financial corporate sector, rose substantially (Graph 16.A).

The coexistence of elevated financial vulnerabilities and high inflation globally makes the current conjuncture unique for the post-World War II era. The tighter monetary conditions needed to bring down inflation could cast doubt on assets – including housing – priced for perfection on the assumption of persistently low real interest rates and ample central bank liquidity. Even traditionally more secure assets could be exposed. Bonds, for example, have provided a safe haven for investors in the low-inflation environment of recent decades. During this phase, bad economic times, when the prices of riskier assets like equities typically fall, were generally met with monetary easing, which boosted bond prices (Graph 16.B). But when inflation is high, economic downturns are more likely to be triggered by tighter monetary conditions, causing both bond and stock prices to fall.

The effects of tighter monetary conditions would also be felt through higher debt repayments. The largest strains are likely in countries where floating rate loans – sensitive to higher policy rates – are more common (Graph 16.C). In this regard, several small open economies look particularly exposed, at least in their household sectors. For firms, floating rate loans are more common among riskier segments. In principle, the aggregate savings built up early in the pandemic could provide buffers for households and firms to cope with higher rates, at least initially. However, the incidence of higher savings may not match that of debt burdens.

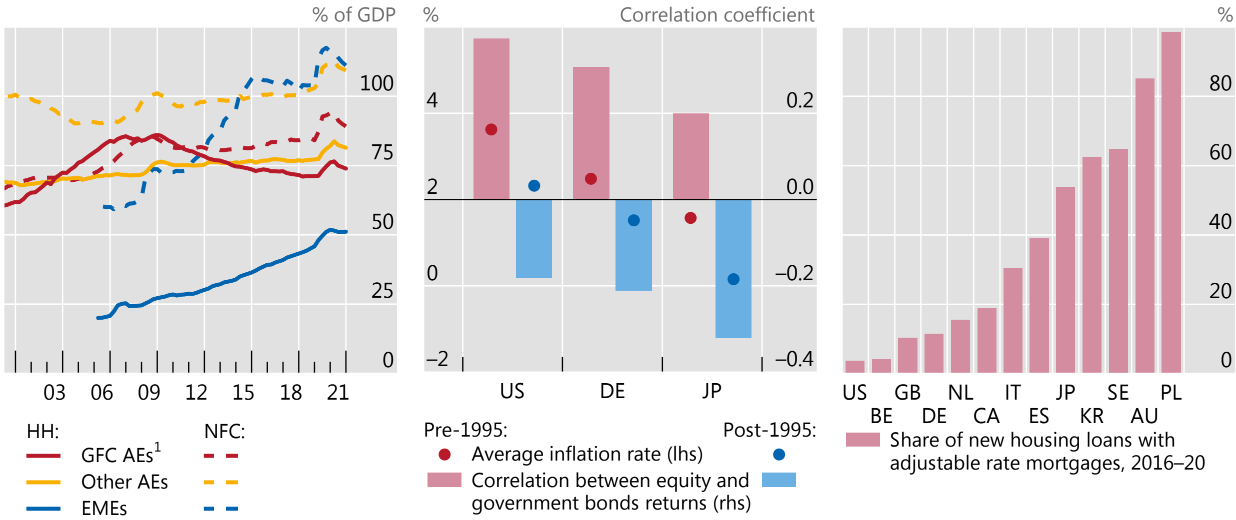
The consequences of these vulnerabilities for economic activity will depend on how high interest rates rise and how asset prices and debt servicing burdens respond. Illustrative simulations based on historical relationships between financial and economic variables can shed light on the key risks. Particularly in countries

Financial vulnerabilities and high inflation: where are the risks? — Graph 16

A. Private sector debt-to-GDP near historical highs in most countries[1]

B. Asset return patterns change under high inflation[2]

C. Floating rate housing loans pose a risk when rates rise



HH = households; NFC = non-financial corporations.

[1] ES, FR, GB, GR, IE, IT, PT and US. [2] Data starting in 1985.

Sources: IMF; Bloomberg; Datastream; European Mortgage Federation; ICE BofAML; national data; BIS.

Box B

The real estate sector's evolving contribution to China's growth

The real estate sector plays a major role in China's economy. Residential investment increased steadily in the first decade of the 2000s, and has remained elevated since, accounting for a much larger share of GDP than in other major economies (Graph B1.A).[1] The real estate sector has also contributed to China's credit expansion, leading the authorities to take actions to reduce leverage. Given the prominent role of housing credit booms and busts in past financial crises and recessions globally, and the strong correlation between housing sector downturns and recessions, understanding the contribution of real estate to Chinese growth, and its implications for the outlook, is of first-order importance.[2] This box highlights the sizeable contribution of the housing sector to China's slowdown over the past year.

The analysis uses province-level housing market data and relates these to country-level GDP.[3] Since local economic conditions exert a large influence on housing sector activity, province-level indicators can help identify developments that national-level data obscure. Moreover, from a methodological perspective, province-level data provide more variation in the variables that are being analysed, which helps to pin down economic relationships.[4]

The relationship between the real estate sector and China's GDP growth strengthened in the 2010s. While province-level measures of housing activity, such as floor space starts, show no significant link with subsequent GDP growth pre-2010, a significant link emerges after 2010 (Graph B1.B). This is consistent with the increasing share of residential investment in China's output.

Housing sector indicators can also help forecast GDP. In particular, a measure of oversupply of housing at the provincial level – computed as floor space starts less floor space sold – signals lower GDP growth over a two-year horizon (Graph B1.C). A similar relationship, albeit with the opposite sign, holds for floor space starts and residential investment activity at a one-year horizon. These relationships capture the direct and indirect effects of residential investment on GDP, eg from spillovers to other sectors, such as real estate services, production of construction materials and home improvement-related retail sales.[5]

These results confirm that the slowdown in the housing sector is likely to have had a material effect on China's growth over the past year. To give a sense of the magnitudes, the estimates suggest that, if growth in floor space starts and residential investment had stayed at their average levels in 2018–19, and growth in housing oversupply at its 2018 level, real GDP growth (year-on-year) would have been some 1–1.5 percentage points higher in 2021. That said, such estimates are by their nature uncertain, in part because they assume that the relationships between the variables remain stable and that the causation runs exclusively from the

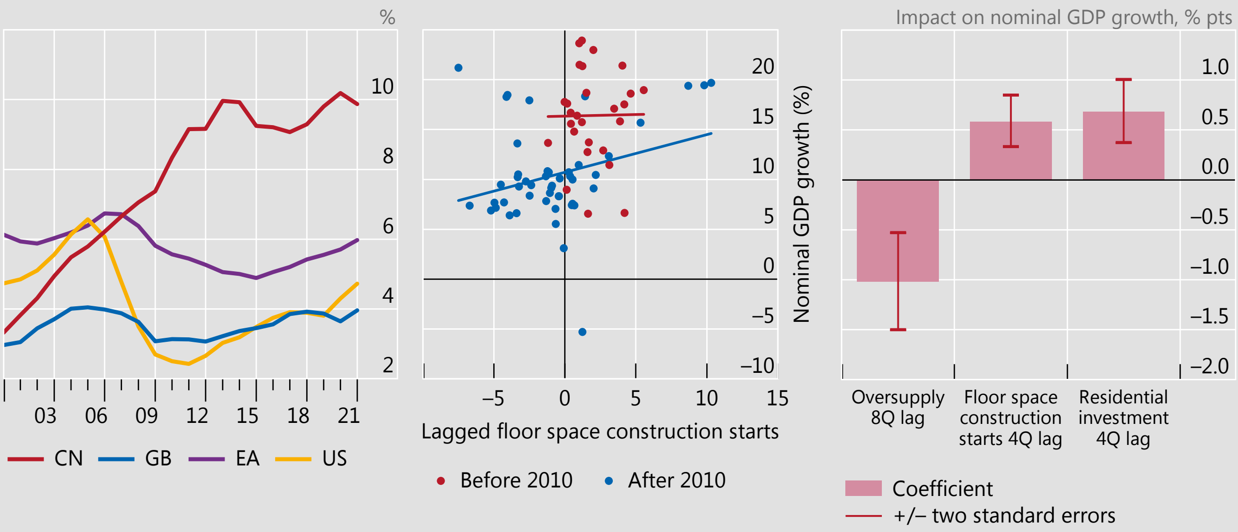
Real estate sector and economic activity in China[1]

Graph B1

A. Residential investment to GDP

B. Real estate and GDP: a strengthening link

C. Forecasting GDP with real estate sector variables



[1] See technical annex for details.

Sources: IMF; Bloomberg; CEIC; national data; BIS.

real estate indicators to GDP. Moreover, the model does not explicitly control for financial factors or changes in housing market policies, including macroprudential measures, which are also likely to have contributed to China's housing market dynamics.[6]

[1] For analysis on China's housing boom, see Fang et al (2015) and Glaeser et al (2017). [2] See Jordà et al (2016), Leamer (2015) and Kohlscheen et al (2020). [3] For detailed analysis, see Kerola and Mojon (2022). [4] Indeed, aggregated province-level housing market indicators explain a larger share of the variation in China's GDP growth than aggregate country-level housing data; the opposite is true for exports and imports, where country-wide measures prove more informative. This result is obtained by aggregating information from province-level data by principal component analysis and then comparing with nation-wide indicators. [5] Accounting for sectoral linkages and spillovers by means of input-output tables, Rogoff and Yang (2021) argue that the impact of the real estate sector on China's GDP is close to 30%. In this comparison as well, China's real estate sector appears larger than those in other major economies. [6] See Kuttner and Shim (2016).

where a large portion of debt is at fixed rates, it will take some time for the interest rates faced by households and firms to reflect higher policy rates (Graph 17.A and 17.B). Despite these lags, average AE private sector debt service ratios (DSRs) could rise by more than 1 percentage point by 2025, to their highest level in over a decade, if central bank policy rates evolve as financial markets currently expect (Graph 17.C). If rates were to mirror the larger 425 basis point increase in the federal funds rate in the 2004–06 period, average DSRs could increase by more than 2 percentage points, reaching their pre-GFC peak.

In this environment, asset prices could come under pressure. According to the simulations, the path of real house prices would resemble that around the GFC, while the long post-GFC run-up in equity prices would start to retreat (Graphs 17.D and 17.E). In contrast, if policy rates were to remain at their current levels, asset prices and debt levels would continue to rise, implying a further build-up in vulnerabilities.

Such shifts in DSRs and asset prices could have a material effect on economic activity. The simulations suggest that the level of GDP in the average AE would be about 1.5% lower under the market interest rate path than it would be if policy rates were held constant (Graph 17.F). In the steeper "2004 tightening" scenario, the level of GDP would be around 3% lower. Even these results may understate the GDP response to tighter monetary conditions, which would occur against a backdrop of historically high debt levels, whose effects on growth may be felt more keenly when asset prices are falling, and the growth headwinds of the higher commodity prices and enhanced geopolitical uncertainty described above.[16]

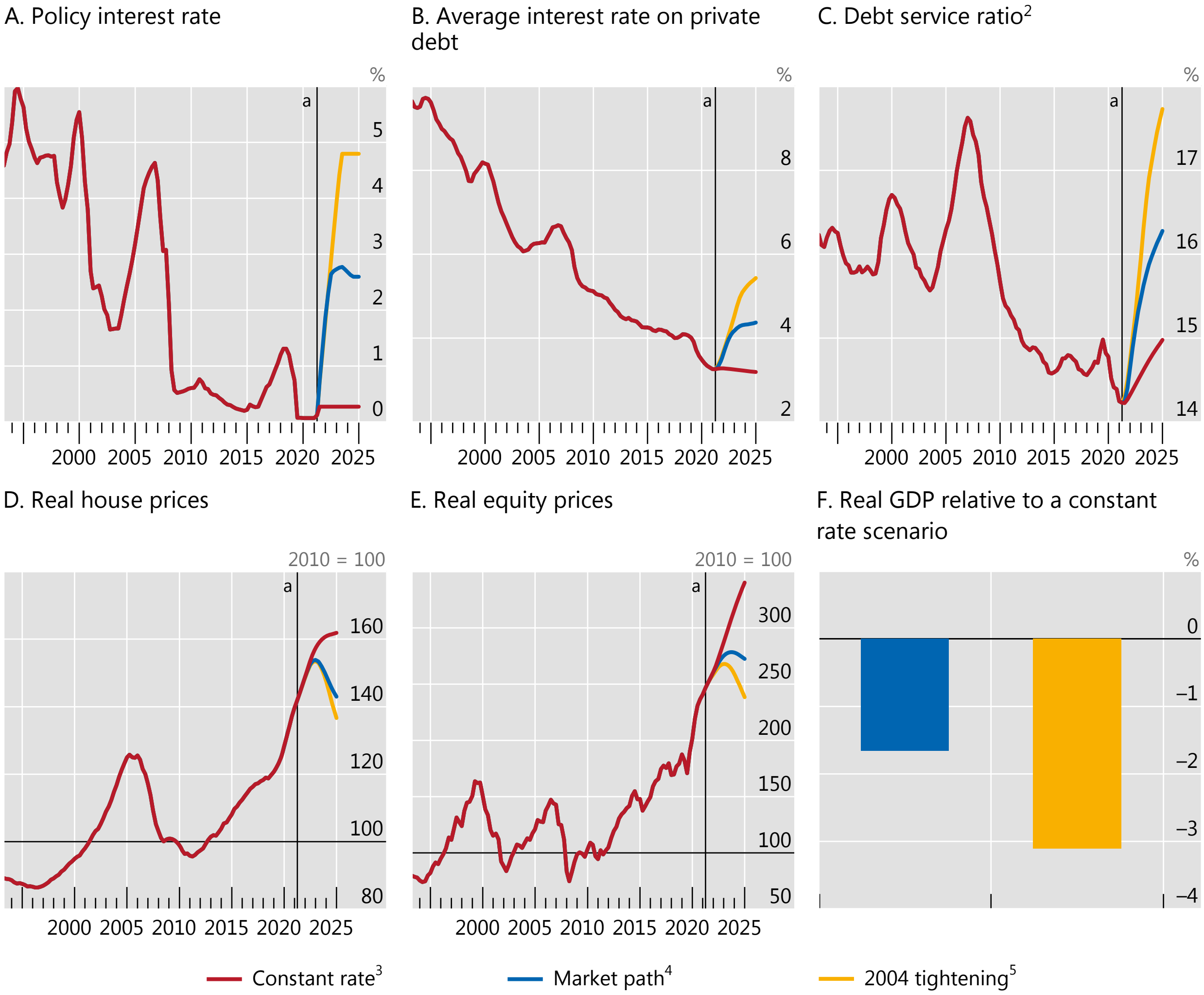
Naturally, the results of this simulation exercise are purely illustrative. In particular, they are based on average historical relationships since the mid-1980s, which may have evolved over the past four decades. The use of cross-country averages also masks considerable variation in exposure to higher policy rates across jurisdictions. And, even for individual countries, the simulations are subject to considerable uncertainty. Nonetheless, they help to highlight key vulnerabilities and give a sense of the orders of magnitude involved.

Financial system stress

Financial system disruptions could reinforce any slowdown in household and corporate spending. Such disruptions could come from stresses in banks or non-bank financial intermediaries (NBFIs). Consider the two sectors in turn.

An economic downturn against the backdrop of high debt levels would test banks' resilience. Credit losses are most likely to accrue in the medium term, after rising policy rates have passed through into market rates and households and firms have exhausted accumulated buffers.

Financial and real consequences of monetary policy tightening[1] Graph 17



ᵃ Simulations begin.

[1] Weighted average of projected outcomes in a sample of 12 AEs, based on GDP at PPP exchange rates. See technical annex for details. [2] Ratio of interest payments on private sector debt to private sector income. [3] Policy rates remain at their May 2022 levels throughout the projection period. [4] Policy rates evolve according to financial market expectations as of May 2022. [5] Policy rate increases from Q2 2022 at the same rate as in the United States between 2004 and 2006.

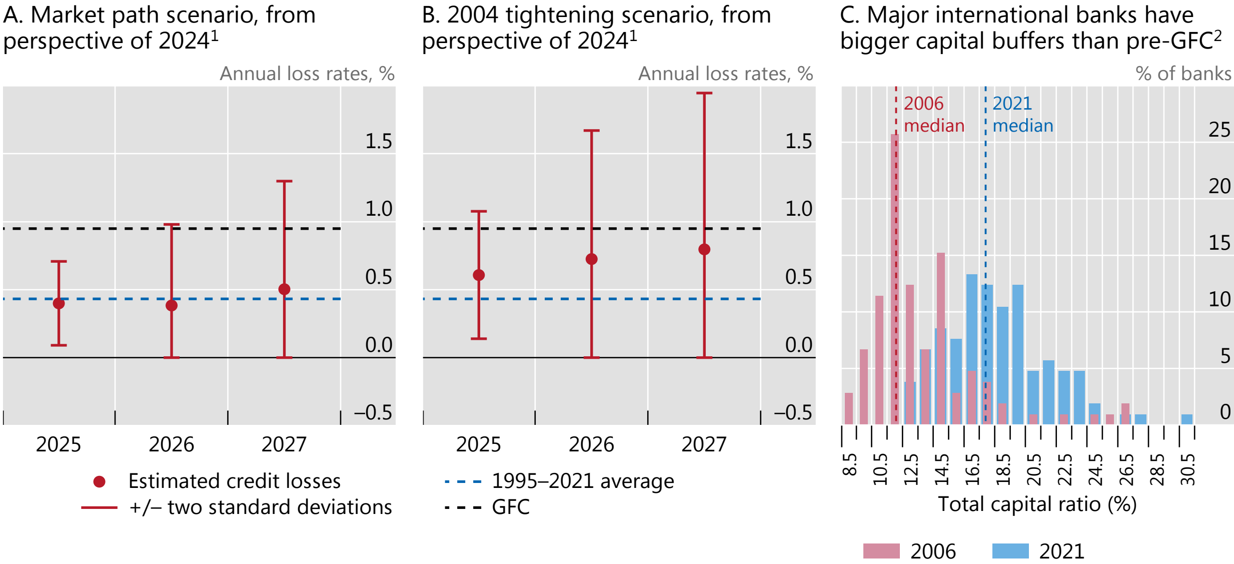
Sources: Bloomberg; national data; BIS.

The size of credit losses will depend on the degree of required policy tightening. If macro-financial conditions follow the "market path" scenario shown in Graph 17 until the end of 2024, past relationships suggest that expected bank credit losses over 2025–27 would be close to historical norms across AEs, albeit with considerable uncertainty (Graph 18.A). They would be larger in the scenario where rates follow the "2004 tightening" scenario shown in Graph 17, somewhat closer to those experienced in the GFC (Graph 18.B). That said, stronger capital cushions mean that banks are in a much better position to take the hit than they were then (Graph 18.C).

Developments in NBFIs could pose greater challenges.

Financialised commodity markets are a key pressure point. These markets came under strain when the war in Ukraine broke out, as sharp rises in commodity price volatility triggered large margin calls in derivatives markets. The frantic search for

Bank credit losses could rise as monetary conditions tighten Graph 18



[1] Medians across a panel of 12 AEs. See technical annex for details. [2] Based on 105 banks that reported their total capital ratio in both 2006 and 2021 (common sample). See technical annex for details.

Sources: Juselius and Tarashev (2022); Fitch Solutions; S&P Capital IQ Pro; national data; BIS.

cash to meet those calls briefly led to stress in dollar funding markets, as reflected in the spreads to OIS of forward rate agreement rates (Graph 19.A). At the same time, some futures markets saw substantial increases in initial margin requirements, leading some commodity traders to stop hedging their exposures in those markets and absorb price risk themselves (Graph 19.B). This, in turn, saw commodity end users, such as airlines, face difficulties hedging their own exposures. While the tensions ultimately eased, the underlying vulnerabilities could resurface if price volatility spikes again.

Some sovereign bond markets could also face strains as monetary conditions tighten. The unwinding of large central bank bond purchases will remove reserves from the banking system and could prove disorderly, as the ructions in US repo markets in September 2019 showed. Already, liquidity in US Treasury markets diminished in late 2021 as broadening inflationary pressures led investors to anticipate an imminent policy shift. Market conditions worsened further as the review period progressed, with implied volatilities in fixed income markets near historical peaks, particularly for short-term rates (Graph 19.C).

As well as market functioning, sovereign credit spreads could emerge as a concern as central banks wind down asset purchases. Some European government bond markets are a case in point, given very high debt levels and past experiences. As credit risk is repriced, these worries could also have a significant impact on financial institutions' balance sheets, probably affecting both securities dealers – key participants of the NBFI ecosystem – and banks, which hold substantial amounts of government bonds in their portfolios.

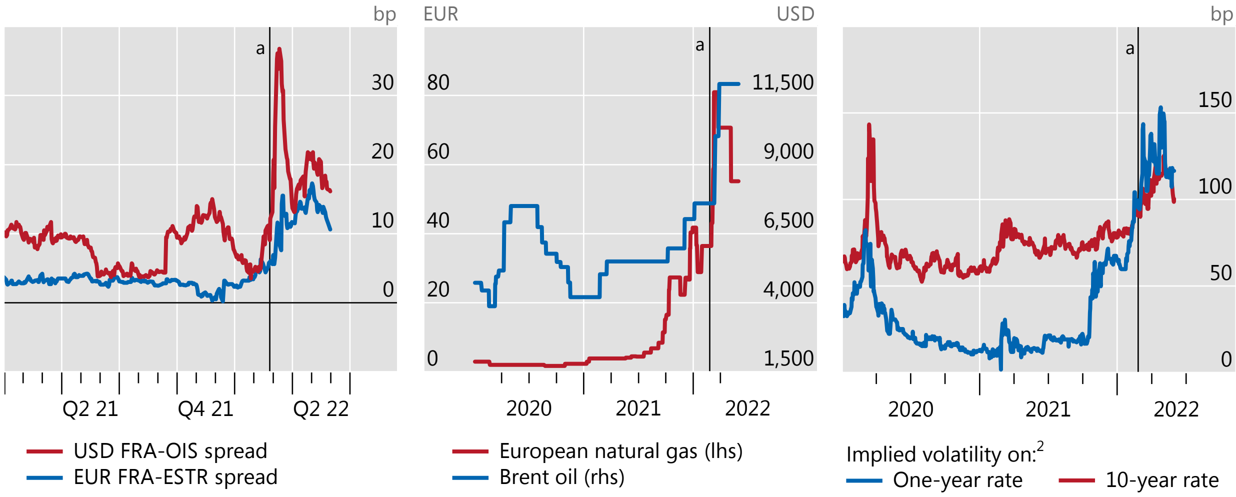
A broader concern is that the extent of exposures among NBFIs, which could transform stresses at individual institutions into more systemic disturbances, are not well known. The collapse of Archegos Capital Management in April 2021, and the attendant stock market disruptions, is a leading example. In that instance, not only was the capital of Archegos largely wiped out, but several banks that provided it with prime brokerage services also took significant hits to their own capital buffers.

Market disruptions could become a key amplification channel | Graph 19

A. Dollar funding cost increased sharply with commodity stress…[1]

B. …and so did initial margins in futures markets

C. Forward-looking gauges of fixed income volatility remained high



[a] Start of war in Ukraine.

ESTR = euro short-term rate; FRA = forward rate agreement; OIS = overnight indexed swap.

[1] FRA-OIS and FRA-ESTR spreads are key bank funding stress indicators. See technical annex for details. [2] Based on USD swaptions with three-month maturity that give the right to enter a one-year or 10-year OIS.

Sources: Bloomberg; ICE (the data have been made available in accordance with the terms of use); BIS.

While the fallout was ultimately contained, it nonetheless highlights the risks posed by hidden leverage in loosely regulated corners of the financial system.

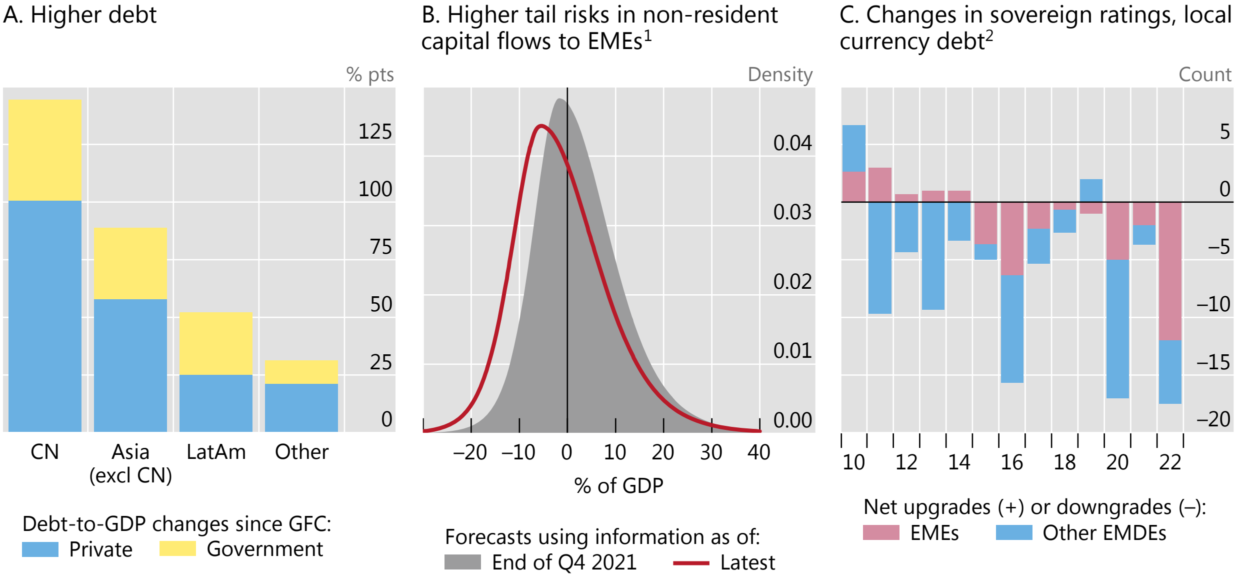
Emerging market economies

The risks discussed above pose tough tests for EMEs. This is despite improvements in fiscal and monetary policy frameworks that, together with greater use of prudential buffers and macroprudential tools, have made EMEs generally more resilient.

Challenges arise because, in some other respects, the starting point for EMEs is worse than in the past. Many are facing tighter financial conditions against a backdrop of high debt, which rose further during the pandemic (Graph 20.A). This raises the prospect of increased capital outflows, which have historically accompanied times of rising global interest rates.[17] The rise in geopolitical tensions at the current juncture amplifies such risks (Graph 20.B). For commodity exporters, the rise in commodity prices counteracts outflow pressures. Nonetheless, a number of sovereigns have recently seen rating downgrades (Graph 20.C).

Many EMEs are highly exposed to stagflationary risks. Growth prospects had already deteriorated pre-pandemic, with potential growth rates on average 2 percentage points lower than before the GFC.[18] In addition, in many EMEs pandemic scarring is more evident than in AEs. By the first quarter of 2022, the median length of full school closures due to Covid-19 had amounted to 29 weeks in Latin America and 16 weeks in emerging Asia, compared with six weeks in AEs.[19] Labour force participation is also recovering more slowly. In Latin America, in particular, participation rates in 2021 were some 2 percentage points below pre-pandemic levels.[20] Many EMEs are highly exposed to slower Chinese growth, especially countries in emerging Asia and some commodity exporters (Graph 21.A). And, in

EME vulnerabilities Graph 20



[1] Conditional distributions of cumulative flows over the next four quarters. See technical annex for details. [2] Average number of yearly up-/downgrades across three major credit ratings agencies. Multi-notch up-/downgrades counted as separate changes.

Sources: Aguilar et al (2022); IMF; Bloomberg; national data; BIS.

countries where vaccination rates lag, health and economic activity could be more vulnerable to further pandemic waves.

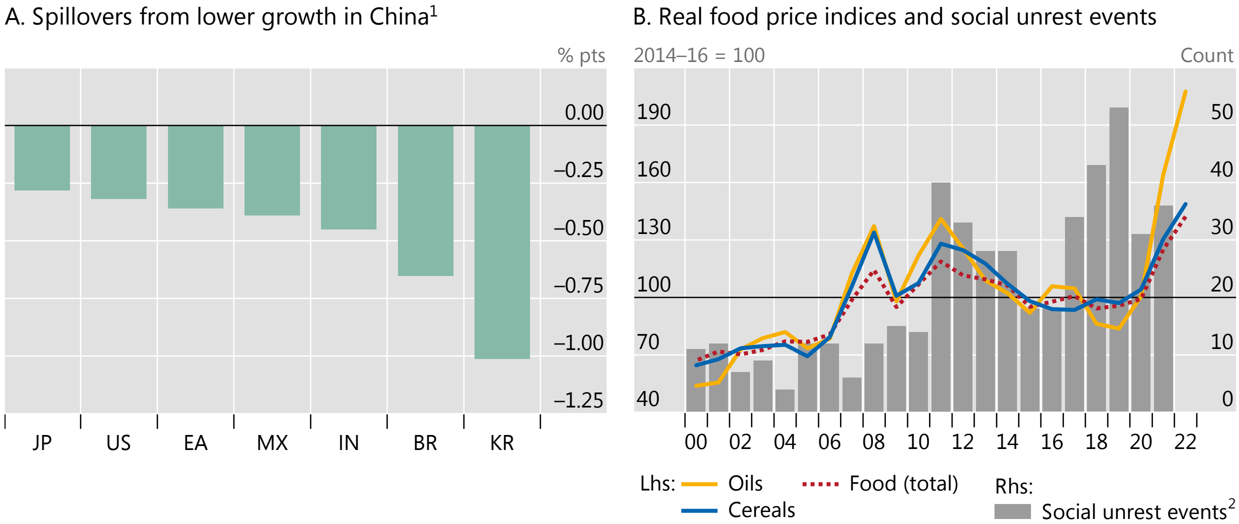
Even if growth does not decline, higher inflation tends to be more disruptive in EMEs. Since inflation expectations are less well anchored in some of these countries, not least in Latin America, larger nominal policy rate increases are required to control inflation. Surging food prices are also more disruptive. Sharp rises in food prices have been associated with social instability and the imposition of export controls in the past, with recent price levels surpassing those seen during the food price spike of 2011 (Graph 21.B).[21] And while regulated food and energy prices, and the associated subsidies, will lower the immediate pass-through to headline inflation in some EMEs, they come with a fiscal cost and can create economic distortions.[22] Combined with growing demands for social spending in the pandemic's aftermath, larger fiscal deficits could eventually feed through into exchange rate depreciations and inflation (Chapter II).

Macroeconomic policy challenges

Recent developments raise a number of macroeconomic policy challenges. High inflation is clearly a major one, further complicated by the fragile growth outlook and financial vulnerabilities. In such an environment, it could be difficult to achieve a soft landing, ie bringing inflation sustainably back to target without sharply restraining the expansion. At the same time, the need to rebuild both monetary and fiscal buffers over the medium term, which has been clear for a long time, remains pressing. The current environment creates an opportunity for sustained monetary policy normalisation, but complicates the task for fiscal policy. Indeed, achieving policy normalisation over the medium term and improving macroeconomic performance more generally will require less reliance on macroeconomic stabilisation

EMEs face spillovers from a slowing China and rising food prices

Graph 21



[1] Real GDP growth response to a 1 percentage point decline in China's growth, after one year. Based on global VAR estimates over 1996–2019. [2] In 130 countries.

Sources: Barrett (2022); Barrett et al (2020); IMF; UN Food and Agriculture Organization; BIS.

policy to sustain growth and a renewed drive to strengthen the productive capacity of the economy.

Controlling inflation

The most pressing challenge for central banks is to restore low and stable inflation without, if possible, inflicting serious damage to the economy. At least in AEs, central banks have not faced this challenge for decades. Historically, achieving such a "soft landing" has proved difficult, and the starting conditions are in many respects unfavourable (Box C). In most countries, inflation rates are much higher than usual at the start of a tightening cycle, and real and nominal policy rates much lower, which suggests that a stronger tightening may be required to bring inflation under control (Graph 22.A). At the same time, elevated asset prices and high debt levels mean that the output costs of tighter financial conditions could be larger than in the past.

The prominent role of relative price changes in driving inflation complicates the policy response. The standard textbook prescription is to "look through" this type of inflation because the tightening required to prevent it would be costly.[23] But that prescription assumes that the resulting inflation overshoot is temporary and not too large. In the light of recent experience, it is harder to argue for such a clear-cut distinction. If relative price adjustments are persistent and higher inflation triggers second-round effects, central banks have no choice but to respond.

Calibrating the response naturally involves a trade-off. Tightening too much and too quickly could inflict unnecessary damage. But doing too little would raise the prospect of a larger and more costly tightening down the road.

For much of the past two decades, central banks had exceptionally ample leeway to lean towards a more accommodative approach. In particular, inflation was generally at or below central bank targets, even where unemployment rates reached multi-decade lows. Of course, trade-offs did not disappear. A decade or more of historically low interest rates contributed to a build-up of financial vulnerabilities and meant that central banks did not rebuild monetary buffers.

Box C

How likely is a soft landing?

Most central banks are now starting to tighten policy, often in the face of high inflation. A key question is whether they will be able to engineer a "soft landing" – ie a tightening cycle that ends without a recession. This box examines what historical monetary policy tightening cycles can teach us about the likelihood of a soft landing and what factors are associated with it.

The first step is to identify policy tightening cycles and soft landings. The analysis is based on tightening cycles in a panel of 35 countries over the period 1985–2018. A tightening episode is defined as one in which the nominal monetary policy rate increases in at least three consecutive quarters.[1] The tightening cycle ends when the policy rate peaks before a subsequent decline. If an economy enters a recession, defined as two consecutive quarters of negative GDP growth, in the three years after the peak of the policy cycle, the landing is defined as a hard one. If the economy avoids a recession, the landing was soft.[2] Historically, about half of all monetary policy tightening cycles have ended in a soft landing, as defined above.

Tightening cycles that end in hard landings differ from those that end in soft landings in several respects. A key one is that hard landings are more likely when monetary tightening is preceded by a build-up of financial vulnerabilities. In particular, faster growth in credit relative to GDP prior to a tightening episode is associated with hard landings (Table C1, top panel). Intuitively, financial vulnerabilities are likely to reinforce the contractionary effects of tighter monetary policy on GDP growth. Moreover, heightened vulnerabilities mean that a growth slowdown is more likely to trigger a recession. The influence of credit growth on the probability of a hard landing is also consistent with the observation that financial cycle peaks have tended to coincide with recessions since the early 1980s, lining up with the sample in this exercise.[3]

Financial vulnerabilities are more likely to emerge when interest rates are low. Reflecting this, hard landings are also commonly associated with low real interest rates prior to the start of the tightening episode. For example, the average real policy rate at the start of tightening cycles that end in hard landings is 0.4%, compared with 1.4% at the start of those that end in soft landings. Inflation is also on average higher before hard landings than it is before soft ones, although the difference between the two is not statistically significant.[4]

The policy rate trajectory during a tightening episode can also influence the likelihood of a soft landing. In particular, hard landing episodes tend to involve increases in policy rates that play out over a longer time (middle panel of Table C1). However, neither the average speed of a policy tightening, nor the size of overall

Hard and soft landings[1]

Table C1

	Variable	Soft landings	Hard landings
Conditions at the start of the tightening cycle	Inflation (%)	2.6	4.1
	GDP growth (%)	2.6	2.7
	Real policy rate (%)	1.4*	0.4*
	Change in household credit-to-GDP (% pts)[2]	2.8*	6.4*
Conditions during tightening	Real policy rate increase (% pts)	0.8	1.3
	Average quarterly real rate increase (% pts)	0.2	0.2
	Tightening duration (quarters)	4.9*	5.9*
Conditions after tightening[3]	Change in inflation (% pts)	–1.1	–0.2
	Change in GDP growth (% pts)	–0.7*	–3.8*
	Real policy rate (%)[4]	1.6	–0.4
	Stock price growth (%)	3.1*	–7.7*

[1] Averages for a panel of 35 economies and 129 policy tightening cycles. Growth rates are in per cent and changes in percentage points. The asterisks indicate the statistical significance of the difference between soft and hard landing episodes at the 5% level. The number of observations for the different rows varies between 46 and 64 for soft landings, and between 50 and 65 for hard landings. [2] Over the two years before the start of the tightening cycle. [3] Over the three years after the end of the tightening cycle. [4] Three years after the end of the tightening cycle.

Sources: Datastream; national data; BIS.

tightening, seems to be associated with differences in the likelihood of hard or soft landings. This suggests that there is little to be gained in terms of output from a shallower and more drawn-out tightening path.

What are the consequences of a hard landing, beyond lower GDP growth? Hard landings are more likely to be associated with abrupt stock price falls (bottom panel of Table C1). At the same time, they are more likely to be followed by lower real interest rates, which often become negative. These findings suggest that achieving a soft landing could be key to ensuring a sustainable normalisation of monetary policy settings to allow buffers to be rebuilt over the medium term.

While the analysis above is silent about the underlying policy frameworks, there are a number of ways in which they could increase the likelihood of a soft landing. Some relevant dimensions have seen notable improvements in recent decades. For example, the greater use of macroprudential tools and larger financial system buffers could weaken the relationship between credit growth and hard landings, by increasing the resilience of the economy against shocks. Better anchoring of inflation expectations may reduce the required policy tightening in response to inflationary pressures, through its stabilising impact on wage and price-setting (Chapter II).

[1] We do not consider the role of balance sheet, exchange rate or credit policies in policy tightening. [2] There is no standard definition of a hard landing. The results are unchanged when one defines a hard landing based on the peak-to-trough GDP growth following the end of the tightening cycle. The results are also similar when a horizon of two rather than three years is considered after the end of the tightening cycle. [3] See Borio et al (2018). [4] Because most of the tightening cycles in the sample occurred after central banks had adopted inflation targeting, or similarly credible policy regimes, the results may understate the adverse effects of high inflation and de-anchored inflation expectations on the likelihood of experiencing a hard landing.

The new inflationary environment has changed the balance of risks. Gradually raising policy rates at a pace that falls short of inflation increases means falling real interest rates. This is hard to reconcile with the need to keep inflation risks in check. Given the extent of the inflationary pressure unleashed over the past year, real policy rates will need to increase significantly in order to moderate demand. Delaying the necessary adjustment heightens the likelihood that even larger and more costly future policy rate increases will be required, particularly if inflation becomes entrenched in household and firm behaviour and inflation expectations (Graph 22.B).

Policy normalisation

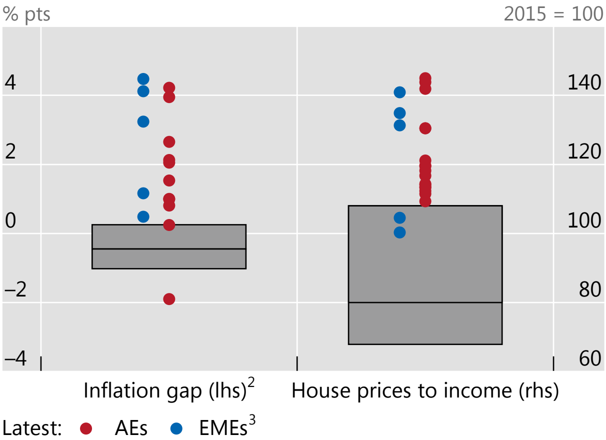
A second macroeconomic policy challenge is to deliver a durable policy normalisation. As discussed in last year's Annual Economic Report, this requires achieving macroeconomic objectives consistent with central bank mandates *and* room for policy manoeuvre. The pandemic and the war in Ukraine have highlighted the imperative to hold buffers so that macroeconomic policy can deal not only with inevitable, cyclical recessions, but also truly unanticipated events.

Such an outcome is by no means guaranteed. Even in countries where financial markets anticipate rapid monetary tightening, long-term bond yields still point to very low policy rates at the peak of the adjustment, often negative in real terms (Graph 23.A). Few fiscal authorities project a material decline in public debt in the years ahead, even though the constellation of real interest rates is substantially below real GDP growth rates, thereby greatly favouring a debt drawdown.[24] Indeed, higher energy and food prices have been creating substantial pressure for more government spending to ease cost of living pressures.

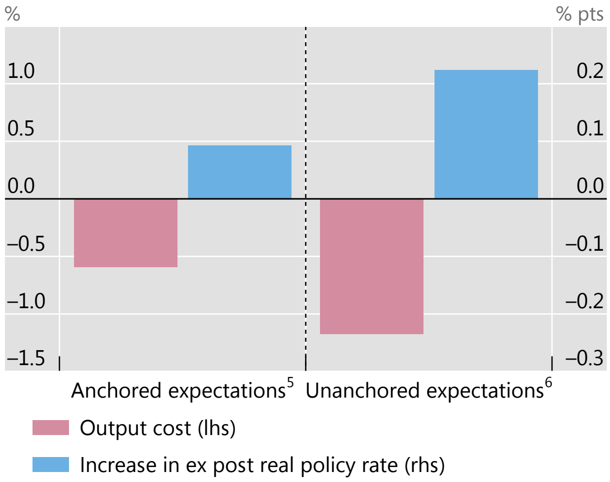
Some governments have already stepped up spending, and further expenditures, often untargeted, loom on the horizon. Germany, the Philippines, Sweden and the United Kingdom, for example, have announced cash transfers to vulnerable households to alleviate cost of living increases, while France and Korea have temporarily lowered sales taxes on energy products.[25] Brazil and Turkey have cut import tariffs on food. In Europe, proposed increases in defence expenditure could

Lowering inflation: initial conditions Graph 22

A. Unusually high inflation and asset prices for the start of a tightening[1]



B. Disinflation will be more costly if expectations de-anchor[4]



[1] Box plots indicate median and interquartile ranges of each variable at the starting time of tightening cycles from 1985 to 2021 for AU, CA, CH, DK, EA (from 1999), GB, JP, NO, NZ, SE and US. [2] Deviation from the target inflation rate. [3] KR, MX, PL, RU and ZA. [4] See technical annex for details. [5] Model simulation where all agents have model-consistent expectations. [6] Model simulation where agents' inflation expectations are an equally weighted average of model-consistent and adaptive expectations.

Sources: OECD; Bloomberg; national data; BIS.

also have a material impact on public finances. Commitments to address climate change add further pressure on fiscal positions globally. And less visible fiscal commitments linked to ageing populations loom large.

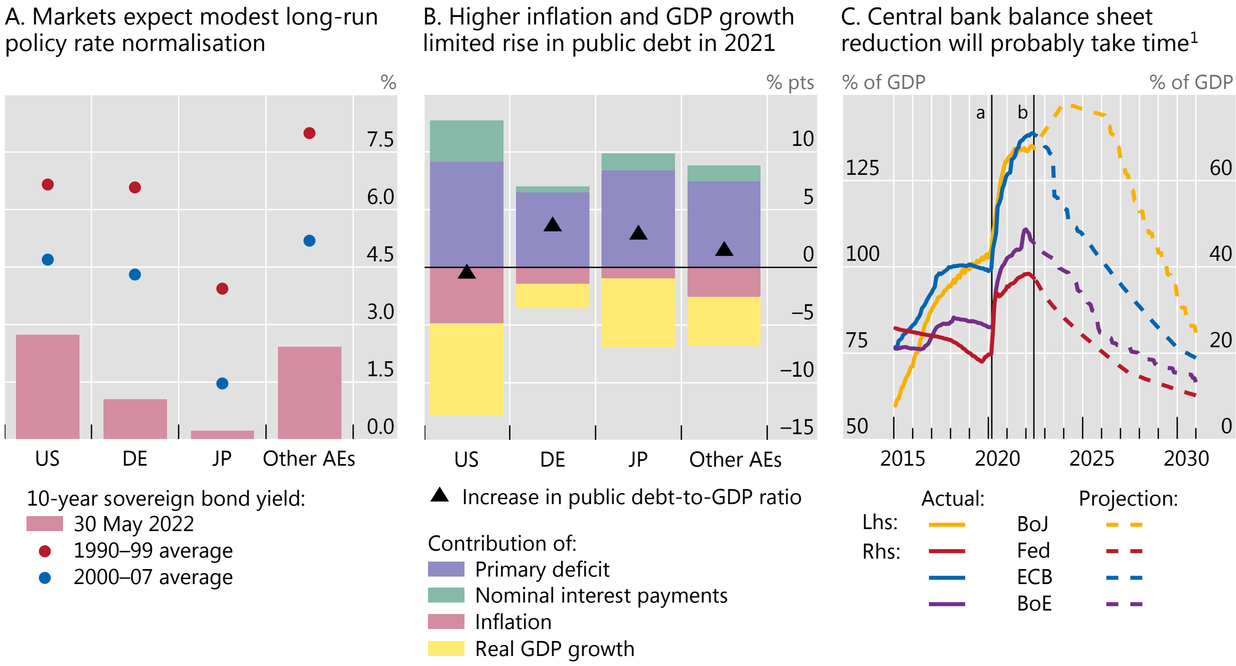
A major difference from previous years is higher inflation. In the near term, this provides a pressing reason to normalise monetary policy. Moreover, the unexpected inflation burst will erode to some extent the value of long-term fixed income debt. Because it rose much faster than interest rates in 2021, higher inflation helped limit the rise in debt-to-GDP ratios (Graph 23.B). However, surprise inflation is not a mechanism that fiscal or monetary authorities can or should rely on to control public debt over the medium term. If it occurred repeatedly, unexpected inflation could make investors demand a sizeable risk premium. And higher interest rates will make fiscal policy normalisation harder.

The large stocks of government debt held by central banks complicate matters. As explained in last year's Annual Economic Report, they increase the sensitivity of overall fiscal positions to higher rates. In effect, they transform long-term fixed income debt into debt indexed at the overnight rate (the interest rate on bank reserves). The effect can be quite large. Where central banks have used such purchases more extensively, some 30–50% of public debt in the large AE jurisdictions is in effect overnight.[26]

The general picture brings into sharp focus the tensions between fiscal and monetary policy along the normalisation path. These could heighten the pressure on central banks to keep their stance more accommodative than appropriate and delay the already lengthy return of central bank balance sheets to more normal levels (Graph 23.C). This puts a premium on institutional arrangements that safeguard central bank independence and a clear emphasis on the primacy of low and stable inflation as the core monetary policy objective.

Central banks have some options to influence the likelihood of a successful policy normalisation. Choices about the pace and timing of policy tightening, as

Prospects for a durable policy normalisation Graph 23



[a] Covid-19 declared a pandemic. [b] Projections begin.

[1] See technical annex for details.

Sources: ECB; Bank of Japan; Bank of England; Federal Reserve Bank of St Louis, FRED; IMF; OECD; Bloomberg; national data; BIS.

well as the sequencing of balance sheet adjustment and interest rate increases, could all influence the smoothness of the process. Effective communication is critical. Here, central banks face a trade-off between forward guidance and flexibility. Setting clear guidelines and benchmarks for policy normalisation could help steer financial markets and reduce disruptions as interest rates rise. But if forward guidance is interpreted as a degree of pre-commitment, it can curtail the central banks' flexibility to respond to evolving conditions. This flexibility is essential.

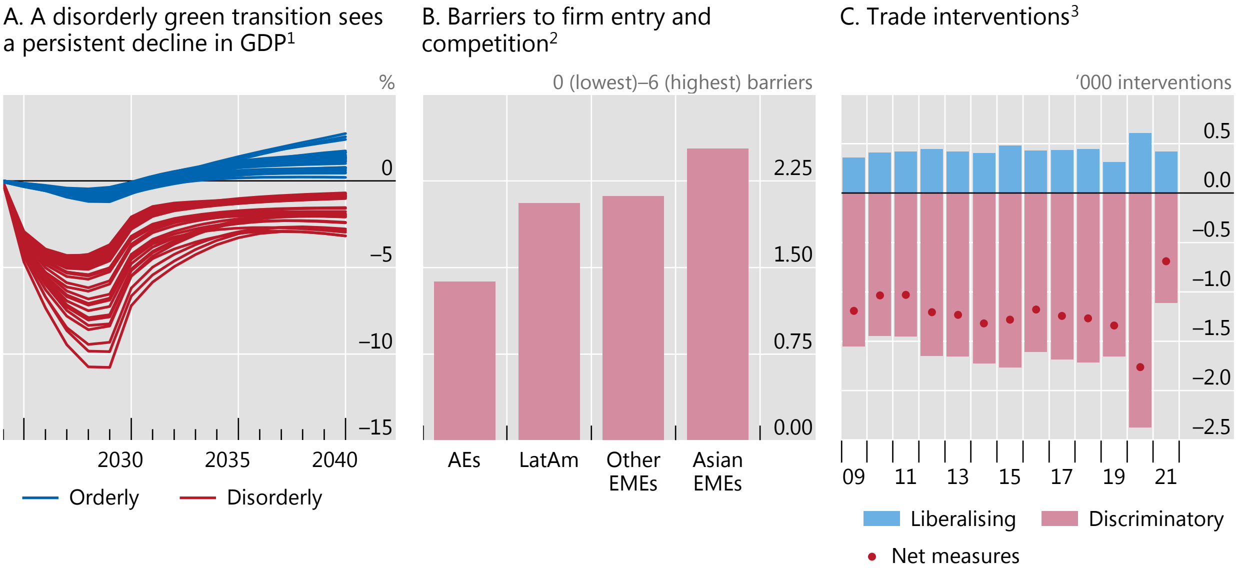
Rebooting the supply side

The experience of the past year, ranging from supply chain bottlenecks to conflict-induced stagflationary pressures, reinforces the importance of reigniting growth-friendly expenditure, in particular investment, and supply-side reforms. These could raise growth and make it more resilient, thus facilitating the normalisation of monetary and fiscal policies over time. To the extent that some of the measures will involve carefully targeted expenditure increases that provide benefits only further down the road, in an environment of limited fiscal space, there is also a premium on making the tax system more growth-friendly.

As one of the most urgent tasks, the green transition calls for targeted measures to put in place a more durable and sustainable energy mix. Simulations suggest that an orderly transition that features a timely increase in green energy investment could impose relatively small near-term costs and deliver persistent long-term gains, measured in terms of economic output (Graph 24.A). By contrast, a disorderly shift, where the adoption of clean energy technology lags but carbon-intensive energy sources are shut down rapidly, would involve significant costs in both the short and long run. The war in Ukraine has sharpened

Importance of reigniting supply side reforms

Graph 24



[1] Projected GDP level paths for 33 countries under the two scenarios for green transition considered in Nodari et al (2022). [2] AEs = CA, DE, FR, GB, IT, JP and US; Other EMEs = AE, PL, RU, SA, TR and ZA. [3] Discriminatory interventions are shown with a negative sign.

Sources: Nodari et al (2022); OECD; Global Trade Alert; BIS.

the focus on energy security, which, especially over the longer run, is consistent with the push to "green" the economy. That said, in the near term, energy security considerations are likely to delay the green transition in some countries by increasing the demand for coal and shale gas, for example. Moreover, the near-term transition costs could be higher than conventionally assumed and may create additional fiscal burdens.

To raise sustainable growth, and where fiscal space allows, many countries could benefit from increased spending on human and physical capital. Increased and better targeted education spending would help compensate for losses in schooling and skills during the pandemic, especially in countries with lower income levels. Pre-pandemic, the average length of schooling was around five years shorter in emerging Asia (eight years) than in AEs (13 years); in Latin America, the difference from AEs was around four years.[27] As to physical capital, investment to improve the state of public infrastructure, if carefully chosen and effectively implemented, could make economies better prepared to deal with any future shocks, be they health or natural disasters, and support the smooth functioning of global trade.[28]

Another priority is to maintain competitive and open markets and avoid real and financial fragmentation, especially in the face of geopolitical tensions and surging food prices. Lowering barriers to firm entry and competition would help accommodate pandemic-induced shifts in consumer preferences and lift businesses closer to the productivity frontier (Graph 24.B). Recent years have seen an increase in restrictive trade measures, and high food prices raise the risk of further export restrictions (Graph 24.C). In the aftermath of the pandemic and in response to rising geopolitical risk, supply chains are likely to see some adjustments, including reshoring, aimed in part at increasing their resilience. While some of these adjustments are necessary and desirable, it will be important to fend off growing impulses in favour of nationalism and fragmentation, given the importance of trade for global growth and productivity.

More generally, the need for structural reforms underscores that higher and durable growth cannot be achieved only through macroeconomic stabilisation policies. The repeated and systematic use of such policies over the past decade in the face of economic weakness, combined with difficulties in rebuilding buffers in good times, is one reason why the room for macroeconomic policy manoeuvre has declined so much over time. A change in direction is urgently needed.

Endnotes

1 See also Chapter II.

2 See Budianto et al (2021).

3 Because the increase in demand was particularly strong for internationally tradeable, durable goods, expansionary fiscal measures may also have had large international inflationary spillovers; see de Soyres et al (2022).

4 See Banerjee et al (2020) and Mojon et al (2021).

5 As shown in Graph 3, price growth in the services sector – which was more affected by pandemic-related restrictions – generally picked up in the year under review, albeit not to the same extent as goods prices.

6 See Santacreu and LaBelle (2022) and Shin (2021).

7 See Rees and Rungcharoenkitkul (2021).

8 See also Chapter III.

9 According to Hernández de Cos (2022), 30% of collective bargaining agreements in Spain in the first three months of 2022 linked final wage increases to inflation, up from 17% in 2021.

10 See Igan et al (2022) for estimates of the effects of commodity price movements on growth and inflation.

11 Particularly in some oil exporters, much of the revenue boost will accrue to state-owned enterprises rather than the private sector.

12 Rees (2013) and Kulish and Rees (2017) discuss the different investment implications of temporary and permanent commodity price shocks.

13 See Caldara and Iacoviello (2022).

14 For evidence on the contribution of imports from lower-wage countries to reduced price pressures in AEs, see Auer et al (2013).

15 For estimates regarding the costs of lockdowns in China that take account of trade linkages across cities, see Chen et al (2022).

16 Similarly, the research on "GDP at risk" documents that downside risks to growth increase when financial conditions are tighter; see Adrian et al (2019).

17 See Box I.F in BIS (2021).

18 Potential GDP growth is proxied by Consensus GDP growth forecasts for six to 10 years.

19 Based on UNESCO map on school closures (https://en.unesco.org/covid19/educationresponse) and UIS, March 2022 (http://data.uis.unesco.org).

[20] Based on data from ILO database.

[21] Commodity price increases have also, on occasion, been a source of social tension in AEs, with the "gilets jaunes" protests in France in 2018–19 being a prominent recent example.

[22] For weights of administered and regulated prices in various EME inflation measures, see eg Table 3.1 in Patel and Villar (2016).

[23] See Aoki (2001).

[24] On average, government debt in AEs is projected to decline by just 3 percentage points of GDP, from around 116% of GDP to 113% of GDP, between 2022 and 2027. In EMEs, it is projected to increase by almost 10 percentage points, from 67% of GDP to 77% of GDP. See IMF (2022) and BIS (2021).

[25] See IMF (2022).

[26] See Borio and Disyatat (2021).

[27] Based on data from the World Economic Forum Global Competitiveness Index.

[28] See OECD (2021).

Technical annex

Graph 1.A: Country groups calculated as weighted averages using GDP and PPP exchange rates. "Other AEs" is based on data for AU, CA, CH, GB and SE. "EMEs excl CN" is based on data for AR, BR, CL, CO, HU, ID, IL, IN, KR, MX, MY, PE, PH, RU, SA, SG, TH, TR and ZA.

Graph 2.B: December 2021 year-on-year inflation. Country groups calculated as weighted averages using GDP and PPP exchange rates. "Other AEs" is based on data for AU, CA, CH, GB and SE. "EMEs (excl CN)" is based on data for BR, CL, CO, HK, ID, IN, KR, MX, MY, PE, PL, RU, SA, SG, TH, TR and ZA.

Graph 3: "Other AEs" is an average of AU, CA, CH, DK, GB, NO, NZ and SE, weighted by GDP and PPP exchange rates. "Latin America" is a simple average of CL, CO and MX. "Food and energy" includes alcoholic beverages.

Graph 4.A: Based on data for AU, CA, EA, GB, JP, SE and US.

Graph 4.B: Based on data for AU, BE, CA, DE, ES, FR, GB, IT, NL, PL, SE and US.

Graph 5.A: "Other AEs" is an average of AU, CA, DK, GB, NO, NZ and SE, weighted by GDP and PPP exchange rates.

Graph 5.B: Suppliers' delivery times PMIs are displayed on an inverted scale. Shipping costs correspond to the Freightos Baltic daily containerised freight rate index.

Graph 6.C: Real oil price calculated as WTI crude oil price deflated by US CPI.

Graph 7.C: Based on one-month AUD, CAD, CHF, EUR, GBP, JPY, SEK and USD overnight index swap forward rates. "Other AEs" calculated as the simple average of AUD, CAD, CHF, GBP and SEK.

Graph 8.A: Ex post real policy rate defined as the difference between the policy rate and the year-on-year inflation rate. Country groups calculated as simple averages. "Other AEs" is based on data for AU, CA, CH, GB and SE. For CH, EA, KR, ID and TH, latest data refer to May 2022; for AU, to March 2022; for the remaining countries, to April 2022.

Graph 9.A: Goldman Sachs Financial Conditions index (FCI), which is a weighted average of country-specific riskless interest rates, exchange rate, equity valuations and credit spreads, with weights that correspond to the estimated impact of each variable on GDP.

Graph 9.C: Country groups calculated as simple averages.

Graph 10.A: Based on US dollar exchange rates for AUD, CAD, CHF, EUR, GBP, JPY, NOK, NZD and SEK.

Graph 10.B: Country group indices calculated as simple averages. "Latin America" is based on data for BR, CL, CO, MX and PE.

Graph 10.C: The risk-adjusted interest rate differential corresponds to the carry-to-risk ratio. This is calculated as the 12-month US dollar interest rate spread over corresponding country rates in their respective local currencies, as implied by forward and spot exchange rates, divided by the option-implied volatility of the exchange rate. "Other AEs" based on US dollar exchange rates for CHF, DKK, EUR, GBP, JPY, NOK and SEK.

Graph 11.A: Each rating bucket is constructed from GDP and PPP exchange rate-weighted averages of euro area and US ICE BofA ML corporate spread indices.

Graph 11.B: Country groups calculated as weighted averages using GDP and PPP exchange rates. "EMEs (excl CN)" is based on data for BR, CL, CO, CZ, HK, HU, ID, IN, KR, MX, MY, PE, PH, PL, RU, SG, TH, TR and ZA.

Graph 11.C: Cyclically adjusted price-to-earnings (CAPE) ratios are calculated by dividing a company's stock price by the average of 10 years of earnings, adjusted for inflation. Country groups calculated as weighted averages using GDP and PPP exchange rates. "Other AEs" is based on data for AU, CA, CH, EA, GB, JP and SE.

Graph 12.A: "AEs" is based on data for AT, AU, BE, CA, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, JP, NL, NO, NZ, PT, SE and US. "EMEs" is based on data for AR, BR, CN, CO, CZ, HU, ID, IN, MX, MY, PE, PH, PL, RO, SG, TH, TR, VN and ZA.

Graph 12.C: "Other AEs" calculated as the simple average of AU, CA, DK, GB, NZ and SE.

Graph 13.B: Country groups calculated as simple averages. "LatAm" is based on data for BR, CL, CO and MX.

Graph 13.C: Group exchange rate calculated as the GDP (PPP)-weighted average of country-specific US dollar exchange rates. An increase in the group exchange rate denotes an appreciation against the US dollar. Commodity prices correspond to the Bloomberg Commodity Index (BCOM).

Graph 14: Mean group estimates of the effect of a 10% rise in oil and agricultural commodity prices on: year-on-year headline and core inflation after 12 months (Graph 14.A), real GDP after two years (Graph 14.B), income and expenditure components of GDP after two years (Graph 14.C). Mean group estimates calculated based on country-specific estimates for AU, AT, BE, CA, CH, DE, DK, ES, FI, FR, GB, IT, JP, NL, NO, NZ, SE, US, ZA over the sample from 1972 to 2019. See Igan et al (2022) for technical details of the model and estimation.

Graph 15.A: Labour productivity defined as output per person employed in 2021 international dollars, converted using PPP exchange rates. Observations are three-year non-overlapping averages.

Graph 16.A: Country groups calculated as weighted averages using GDP and PPP exchange rates. "Other AEs" is based on data for AT, AU, BE, CA, CH, DE, DK, FI, JP, LU, NL, NO, NZ and SE. "EMEs" is based on data for AR, BR, CL, CN, CO, CZ, HK, HU, ID, IL, IN, KR, MY, MX, PL, RU, SA, SG, TH, TR and ZA.

Graph 17: Projections are based on country-specific macroeconomic models. The models consist of a VAR linking the behaviour of private sector debt-to-income ratios, real house prices, real equity prices, real income, effective private sector interest rates and real GDP. The coefficients in some VAR equations (eg equity prices) are restricted to reflect realistic information lags. VARs are estimated over the sample Q1 1985–Q4 2019. Policy interest rates are included as an exogenous variable in the model. In each scenario, all variables other than the policy rate evolve according to their estimated relationships in the model.

Graph 18.A–B: Credit losses calculated based on the private sector debt-to-income and credit growth projections shown in Graph 17 using the approach described in Juselius and Tarashev (2022).

Graph 18.C: Total capital ratio is the total capital adequacy ratio under the Basel III framework. It measures Tier 1 plus Tier 2 capital, which includes subordinated debt, hybrid capital, loan loss reserves and the valuation reserves as a percentage of risk-weighted assets and off-balance sheet risks.

Graph 19.A: FRA-OIS and FRA-ESTR spreads increase when investors paying the fixed rate in forward rate agreements demand a higher premium on rates that have to be settled in the future.

Graph 20.A: Country groups calculated as simple averages. Private debt is measured as total credit to the non-financial private sector. "Other" is based on data for CZ, HU, PL, RU, TR, SA and ZA. Change from Q1 2008 to Q1 2022 (if not available, Q4 2021).

Graph 20.B: Based on a "capital flows at risk" model, estimated using panel quantile regressions for EMEs. The model relates gross debt and equity inflows to two-year US government bond yields, commodity prices, and geopolitical and financial risks. The model also includes US and local GDP growth to control for global and local business cycles. Geopolitical risks are measured using the index from Caldara and Iacoviello (2022). Panel based on data for AR, BR, CL, CN, CO, CZ, ID, IN, KR, MX, MY, PE, PH, PL, RO, TH, TR and ZA.

Graph 20.C: "Other EMDEs" includes emerging market and developing economies as defined by the IMF, excluding those already included in "EMEs".

Graph 21.B: Data for social unrest events are shown until end-2021.

Graph 22.A: A tightening cycle is defined as a period of consecutive policy rate hikes with a cumulative increase greater than or equal to 2 percentage points. The definition may differ across the sample. Series for some countries are shorter or missing. The latest data are as of April 2022.

Graph 22.B: Cumulative output loss/average real policy rate increase required to achieve a permanent 1 percentage point decline in inflation. Estimates based on a workhorse three-equation DSGE model (see eg Galí (2015)). In the "anchored expectations" simulations, agents have model-consistent expectations. In the "unanchored expectations" simulations, agents' inflation expectations are an equally weighted average of model-consistent expectations and the previous quarter's inflation rate. The permanent decline in inflation is implemented using the structural change methodology described in Kulish and Pagan (2017).

Graph 23.A: "Other AEs" calculated as the simple average of AU, CA, DK, GB, NZ and SE.

Graph 23.B: 2021 primary deficit measured as general government primary net lending/borrowing; "Other AEs" is weighted average using GDP and PPP exchange rates. Nominal interest payments stemming from gross general interest payments over general government gross debt. Inflation measured as GDP deflator. Nominal interest payments, inflation and real GDP growth components adjusted by the lagged value of debt-to-GDP.

Graph 23.C: Federal Reserve assumed to follow its announced balance sheet reduction path. ECB assumed to end reinvestment in 2025. Bank of Japan assumed to continue net purchases through 2023 and end reinvestment in 2026. Bank of England assumed to follow passive roll-off path.

Graph 24.B: Country groups calculated as simple averages.

Graph A1.B: Commodity prices expressed in real terms. "Present" corresponds to April 2022.

Graph A2.A: Primary energy consumption.

Graph A2.C: Ex post real policy rate defined as the difference between the policy rate and the year-on-year inflation rate.

Graph B1.A: Series employed rely on nominal values. EA calculated as GDP-weighted average of AT, BE, DE, ES, FI, FR, GR, IE, IT, LU, NL and PT.

Graph B1.B: The analysis uses province-level housing market data and relates these to country-level GDP. Based on quarterly data expressed in year-on-year growth rates. Data for floor space construction starts are shown as principal components of province-level data and are lagged by four quarters, as described in Kerola and Mojon (2022). Floor space construction starts refer to the entire floor space of newly started houses by the real estate development enterprises during the reference time.

Graph B1.C: The analysis uses province-level housing market data and relates these to country-level GDP. All variables in the forecasting model are expressed as two-year average growth rates as described in Kerola and Mojon (2022). The explanatory variables are principal components of province-level data. The model also includes dummy variables to account for the early phase of the Covid-19 crisis. Floor space construction starts refer to the entire floor space of newly started houses by the real estate development enterprises during the reference time.

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II. Inflation: a look under the hood

Key takeaways

- To better understand inflation, it is key to go beyond aggregate analysis in order to separate relative from generalised price changes and examine their joint dynamics.
- Periods of high and low inflation are very different, notably with respect to their self-stabilising properties and how firms and workers respond to relative price shifts.
- Preserving a low inflation environment is paramount and requires ensuring that relative price changes do not translate into entrenched inflation. Transitions from low- to high-inflation regimes are especially challenging because they tend to be self-reinforcing.
- Monetary policy has an essential role to play in ensuring the durability of a low-inflation regime through the features of its operating framework as well as through flexible and timely adjustments in the policy stance.

Introduction

The recent remarkable surge in inflation after its long quiescence has raised pressing questions about the dynamics of inflation more generally. In the process, it has put the spotlight on the importance of sector-specific developments including the persistent pandemic-induced shift from services to goods; sectoral bottlenecks in global value chains; and soaring food and energy prices (see Chapter I). An urgent question is whether higher inflation will become entrenched.

These developments have underscored the need to go beyond the aggregate dynamics of inflation in order to shed further light on how its engine works, ie to look "under the hood".

What does this mean, concretely? Many workhorse models of inflation build on a Phillips curve relationship between inflation and economic activity. Taking this approach, inflation fluctuations reflect aggregate demand pressures on productive capacity, temporary supply shocks and changes in inflation expectations. Looking under the hood complements this perspective. It distinguishes clearly between a multitude of relative price changes and underlying inflation itself. It examines in detail how, and under which conditions, such relative price changes can morph into broader-based inflation. And it pays close attention to the wage-price formation process – the core of the inflation engine – illuminating how this depends on the rate of inflation itself and how it is linked to inflation perceptions and expectations. This also means going beyond the well known cyclical drivers of inflation to examine the structural influences on wage- and price-setting. These are often global in nature.

The distinction between relative price changes and underlying inflation is critical. Relative price changes reflect those in individual items, all else equal. This may or may not be related to underlying inflation, ie a broader-based and largely synchronous increase in the prices of goods and services that erodes the value of money and devalues the "unit of account" over time.

Looking under the hood reveals some important features of the inflation process.

Low-inflation regimes turn out to be very different from high-inflation ones.[1] When inflation settles at a low level, it mainly reflects changes in sector-specific prices and exhibits certain self-equilibrating properties. Changes in inflation become less sensitive to relative price shocks, and wage and price dynamics are less closely linked. Moreover, there is evidence that the impact of changes in the monetary policy stance becomes less powerful.

Transitions from low- to high-inflation regimes tend to be self-reinforcing. As inflation rises, it naturally becomes more of a focal point for agents and induces behavioural changes that tend to entrench it, notably by influencing wage and price dynamics. This puts a premium on better understanding how transitions work in order to be able to identify them early enough as events unfold. The transition from a low- to a high-inflation regime in the late 1960s and early 1970s illustrates some of the possible forces at play. These include large and persistent relative price increases – notably oil – in a context of strong cyclical demand and in an environment structurally conducive to wage-price spirals, ie high pricing power of labour and firms coupled with the loss of the monetary anchor provided by the Bretton Woods system.

Monetary policy plays a key role in establishing and hardwiring a low-inflation regime and in avoiding transitions to a high-inflation one. Once a low-inflation regime is established, monetary policy can afford to be more flexible and tolerate more persistent, if moderate, deviations of inflation from targets. Having gained precious credibility, it can reap the benefits. At the same time, monetary policy must ensure that the regime is not jeopardised. It is one thing to tolerate moderate deviations from point targets; it is quite another to put the system's self-equilibrating properties to the test. The costs of bringing inflation back under control can be very high. Calibrating policy to prevent transitions is especially challenging.

This chapter examines inflation in depth, from an under the hood perspective. It starts by defining inflation and characterising its behaviour as a function of its level, drawing on the disaggregated price data that underpin it. It then provides a systematic analysis of wage- and price-setting behaviour and of how changes in relative prices can give rise to inflation, facilitating transitions across regimes. Finally, it explores the key role of monetary policy in securing a low-inflation regime and preventing transitions to a high-inflation one.

Inflation: stylised facts

Conceptually, the term "inflation" encapsulates the notion of an erosion of the purchasing power of money.[2] Inflation can be thought of as a change in the value of the numeraire vis-à-vis all goods and services. When looked at from this perspective, in its purest form, inflation would imply a proportional and synchronous change in all prices.[3] As such, it would leave the relative prices of all goods and services unchanged: only their prices expressed in terms of the numeraire would vary.

In practice, however, price changes are never perfectly synchronous. Different goods and services have different adjustment speeds. This is because the process of changing prices uses valuable firm resources and very frequent adjustments need not be optimal, especially in the presence of long-term relationships between buyers and sellers ("nominal rigidities").[4] For example, the prices of commodities are much more variable than those of, say, manufactured goods and, even more so, of services.

Therefore, inflation, measured as the change in some general and comprehensive price index, will always reflect changes in relative prices in addition to underlying inflation. Some measures of inflation seek to partly disentangle the two, in a very rough fashion, most commonly by excluding the most volatile items. This, however, still misses the rich nature of granular price changes, both transitory and long-lasting, if not permanent. Longer-lasting ones tend to be driven by structural "real" forces, such as changes in consumer preferences and relative productivity trends.

From a historical perspective, focusing on countries with a long history of price data, extended phases of high inflation have been relatively rare. The Great Inflation of the 1970s is the archetypal example. High rates of inflation have also typically followed wars. A look at cross-country historical data since 1870 (Graph 1.A) reveals that inflation was low, although volatile, over the years of the first globalisation era (1870–1914) but surged during World War I and World War II. In the aftermath of World War II, most belligerents experienced high inflation for some years (Graph 1.B). Again, the 1970s stand out for both the length and global reach of inflationary forces.

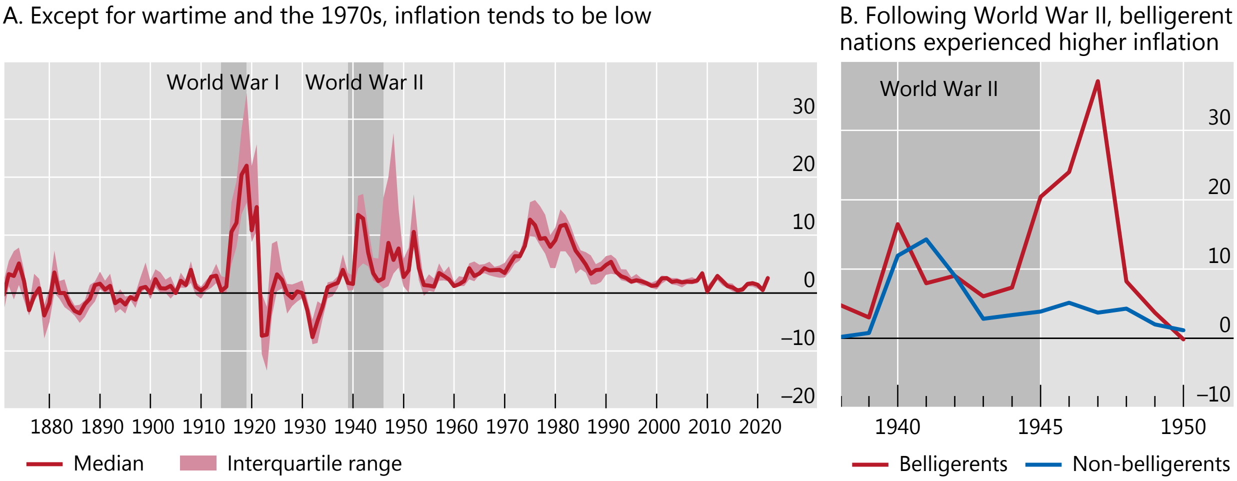
Extremely high-inflation episodes, or hyperinflations,[5] are even less frequent. These typically follow periods of major political upheavals and a generalised loss of confidence in institutions. The defining characteristics of hyperinflations are large budget deficits that are increasingly directly financed by central banks (often due to the inability to collect sufficient revenues via taxes). One consequence is spiralling exchange rate depreciations.[6] Telling examples include post-revolutionary France and the aftermath of World War I in the Soviet Union and Germany. More recently, some countries in Latin America experienced hyperinflation in the wake of the debt crisis of 1982, while Russia saw an inflation rate of around 2,500% in 1992 following the collapse of the Soviet Union.

The dynamics of inflation vary systematically with its level along a number of dimensions, pointing to important differences between low- and high-inflation regimes. In particular, it is well known that when inflation becomes durably low, its volatility tends to fall, as does its persistence.[7] However, looking under the hood at more granular price increases reveals several additional striking features.

Inflation from a historical perspective[1]

In per cent

Graph 1



[1] See technical annex for details.

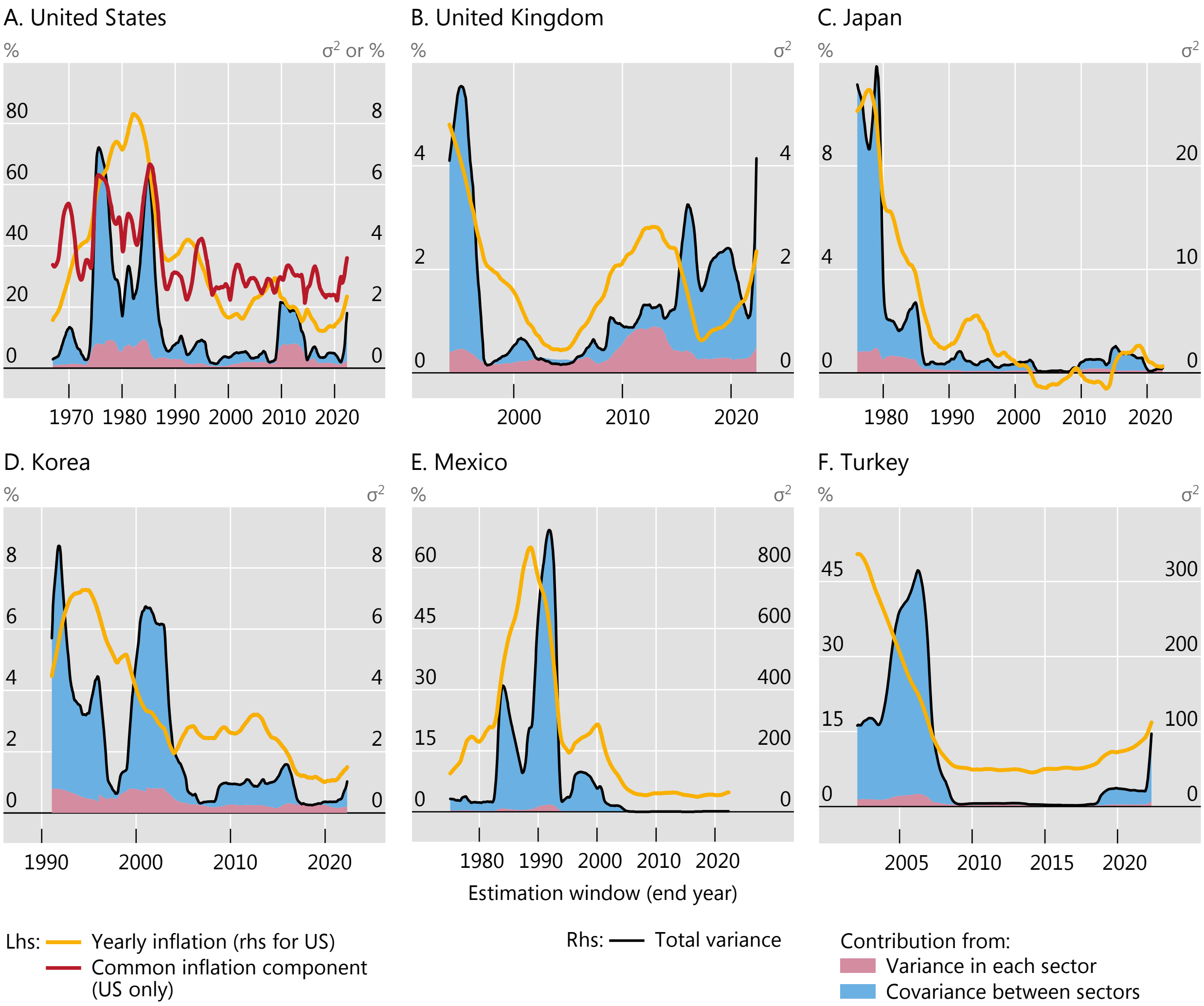
Sources: Global Financial Data; national data; BIS.

First, the reduction in inflation volatility at low levels of inflation is not due to a decline in the volatility of individual price changes but rather to the decline in the correlation between them. This bears a close analogy with the return on a portfolio of securities: the variance of the return is overwhelmingly determined not by the variance of the individual components, but by the correlation across them.

The mirror image of this stylised fact is that, once inflation is tamed, idiosyncratic relative price changes rather than price co-movements explain much of the change in the overall price index. Thus, the common component in the cross section of price changes declines. This is best illustrated with the personal consumer expenditure price index for the United States, for which a long time series of very granular data is available. The common component explains a large share of the total variance of inflation up until the mid-1980s, corresponding to the period when inflation was high, but little thereafter (Graph 2.A). This relationship also holds for other countries, for which the series are shorter (Graphs 2.B–2.F).

Second, and closely related, the degree to which individual price changes spill over into inflation also declines as inflation becomes durably lower. For example, the

Volatility falls in low-inflation regimes as price co-movements drop[1] Graph 2



[1] Consumer price inflation, except US (personal consumption expenditure deflator). Calculated using sector-level data over a five-year rolling window. See technical annex for details.

Sources: CEIC; national data; BIS.

pass-through of outsize price changes to core inflation falls substantially (Graph 3.A). The same is true of the pass-through to inflation of changes in prices that are especially "salient", either because of their pervasive role in production chains (eg oil; Graph 3.B) or because of their weight in consumption baskets (eg food, especially in EMEs). And the same holds for the exchange rate – the relative price of two units of account – given its far-reaching impact on prices in the economy (Graph 3.C).[8]

Third, and consistent with the previous findings, the spillovers across all prices tend to decline in low-inflation regimes. This is illustrated in Box A and Graph 4.A, which documents the phenomenon for a group of advanced economies (AEs) and emerging market economies (EMEs). The transmission of disaggregated sectoral price changes to other sectors, measured by the share of the total variance that these account for, is much higher and more pervasive in high-inflation regimes.

Finally, a more granular perspective sheds further light on the well documented decline in the persistence of aggregate inflation in low-inflation regimes.[9] It shows that this decline is not just a by-product of aggregation, but also reflects less persistent individual price changes. This is quite a general phenomenon, visible for most sectoral prices across a range of countries (Graph 4.B).

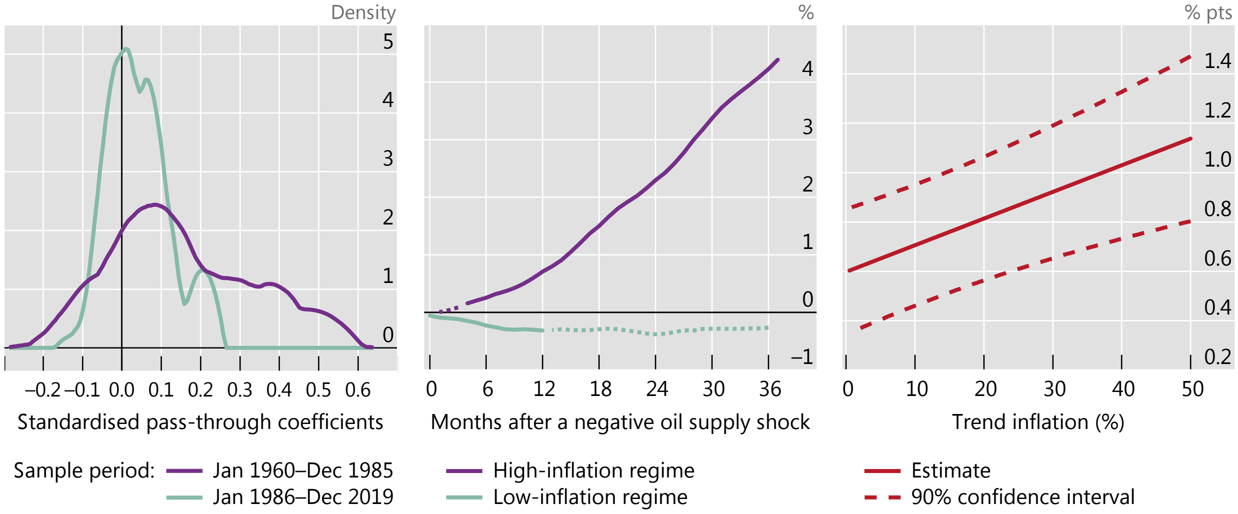
Overall, these findings highlight important differences between high- and low-inflation regimes. In a low-inflation regime, relative price changes, even the salient ones, tend to fade away without leaving a noticeable imprint on aggregate inflation. Hence, the regime is, to a certain extent, self-equilibrating. As such, it tends to become entrenched unless subjected to major shocks that are not met with a sufficient policy response. By contrast, a high-inflation regime does not have such desirable properties and inflation becomes increasingly sensitive to relative price shocks – including large exchange rate depreciations. It is therefore more likely to increase further (see also below).

In low-inflation regimes the pass-through of outsize price changes, oil price increases and FX depreciations to aggregate prices is dampened — Graph 3

A. The pass-through of outsize relative price increases to US core PCE inflation has declined[1]

B. Oil price increases transmit to consumer prices when inflation is high[2,3]

C. The exchange rate pass-through depends on the level of inflation[3,4]



[1] Distribution of the impact of large relative price increases on core inflation. See Borio et al (2021) for details. [2] The solid lines indicate portions of the response that are statistically significant at the 10% level. [3] See technical annex for details. [4] Effect on inflation from month t–1 to month t+2. For trend inflation, five-year moving average of annual headline inflation.

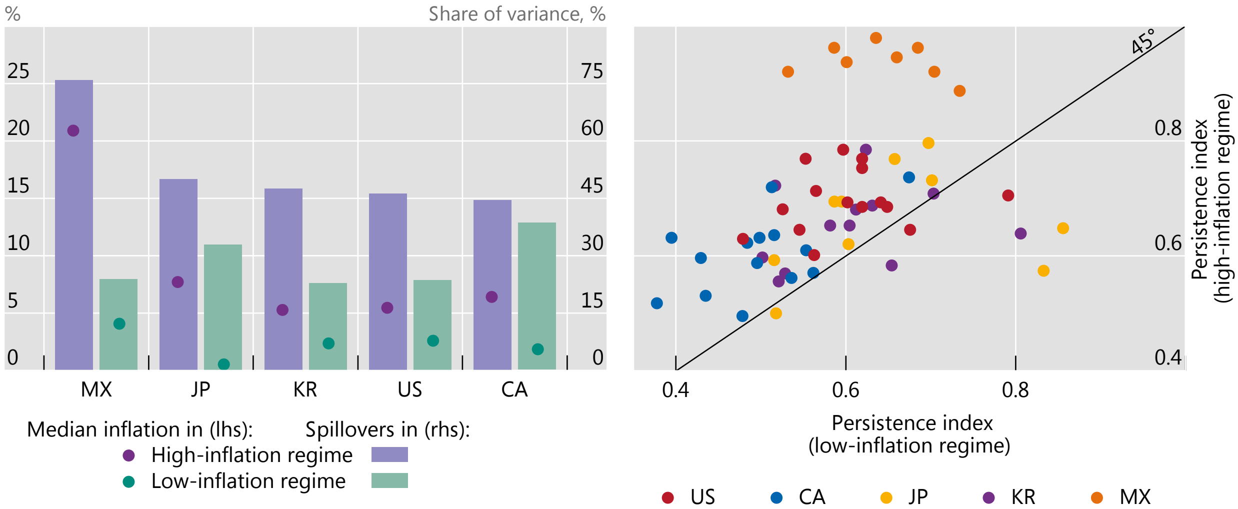
Sources: Baumeister and Hamilton (2019); Borio et al (2021); Federal Reserve Bank of St Louis, FRED; national data; BIS.

Inflation regimes affect the persistence and transmission of sectoral price changes[1]

Graph 4

A. Sectoral price spillovers are more muted in low-inflation regimes[2]

B. Sectoral price changes are less persistent in low-inflation regimes[3]



[1] See technical annex for details, including regime dates. [2] Share of the variance of sectoral price changes explained by shocks to prices in other sectors over a horizon of one year. See Box A for details. [3] Persistence of one-month log price changes computed using sector-level data for the specified country.

Sources: Board of Governors of the Federal Reserve System; Federal Reserve Bank of St Louis, FRED; OECD; World Bank; CEIC; Datastream; national data; BIS.

What explains the inflation process?

What lies behind these stylised price dynamics? How do relative price changes translate into self-sustained increases in the aggregate price level? More generally, what explains the inflation process?

Sustained inflation ultimately involves a self-reinforcing feedback between price and wage increases – so-called wage-price spirals. Changes in individual prices can broaden into aggregate inflation. And they can also erode real wages and profit margins for very long spells. But, ultimately, they cannot be self-sustaining without feedback between prices and wages: profit margins and real wages cannot fall indefinitely. So, beyond the important impact of aggregate demand conditions on wage- and price-setting, a key question is how changes in relative prices that pass through to the aggregate price index ("first-round effects") can trigger feedback between price and wage increases ("second-round effects").

To unravel this process, we need to go beyond the canonical stylised Phillips curve. The Phillips curve provides a useful and relatively easy-to-grasp framework but has a number of features that limit its ability to shed light on the forces behind inflation dynamics (see Box B for a detailed discussion). First, by construction, and for simplicity, it focuses only on an aggregate price index and hence leaves out sectoral developments. While the framework can include some key relative prices, such as those of oil or the exchange rate, these have only a transitory impact on inflation.

Second, the Phillips curve focuses on aggregate cyclical factors as the key drivers of prices (and, implicitly, wages) and does not account for structural forces. Third, inflation expectations are assumed to affect inflation directly, rather than through their impact on individual pricing decisions.[10] Moreover, the various relationships are assumed to be invariant to the level of inflation. While this is a

Box A

Measuring price spillovers across sectors

Examining how shocks to prices in certain sectors transmit and propagate to others can help shed light on how individual price changes are able to morph into broad-based inflation. One relatively simple way to do this is to look at how shocks affecting certain sectoral price indices affect the variability of prices in other sectors within a certain horizon.[1] This box presents indices of price spillovers across different sectors. It does so, first, in the context of sector-level personal consumption expenditure (PCE) deflators for the United States. The analysis is then extended to producer price indices (PPI) categories, to see how the price changes of inputs percolate downstream to those of final goods and services.

The key ingredient for the construction of the spillover indices is the generalised forecast error variance decomposition (GFEVD) matrix.[2] This measures the share of the variance of each PCE sector (the rows) explained by shocks to each of the sectors (the columns). Graph A1 visualises this for a horizon of 12 months for two estimation samples: the first includes the Great Inflation of the 1970s (Graph A1.A), and the second the "Great Moderation", beginning in 1986 (Graph A1.B). Consider, for example, the dark red square in the row "Food services" corresponding to the column for "Food and beverages": it indicates that the bilateral spillovers from the former to the latter are sizeable, as one would expect. Obviously, the diagonal elements of the GFEVD matrix explain the lion's share of each sector's variance. But these are in fact "own" shocks, and do not correspond to spillovers across sectors, and so they are excluded from the heat map.

Going beyond bilateral spillovers, an index of total spillovers can be constructed by summing all the off-diagonal elements of the GFEVD matrix. Given that the matrix in Graph A1.A ("Great Inflation") has overall darker colouring compared with Graph A1.B ("Great Moderation"), the index of total spillovers is higher in the high-inflation regime than in the later low-inflation one, as was also reported in Graph 4.A in the main text. Spillovers across sectors explain about 20% of the total variance over a 12-month horizon in the post-1986 sample, down from more than 45% in the pre-1986 sample.

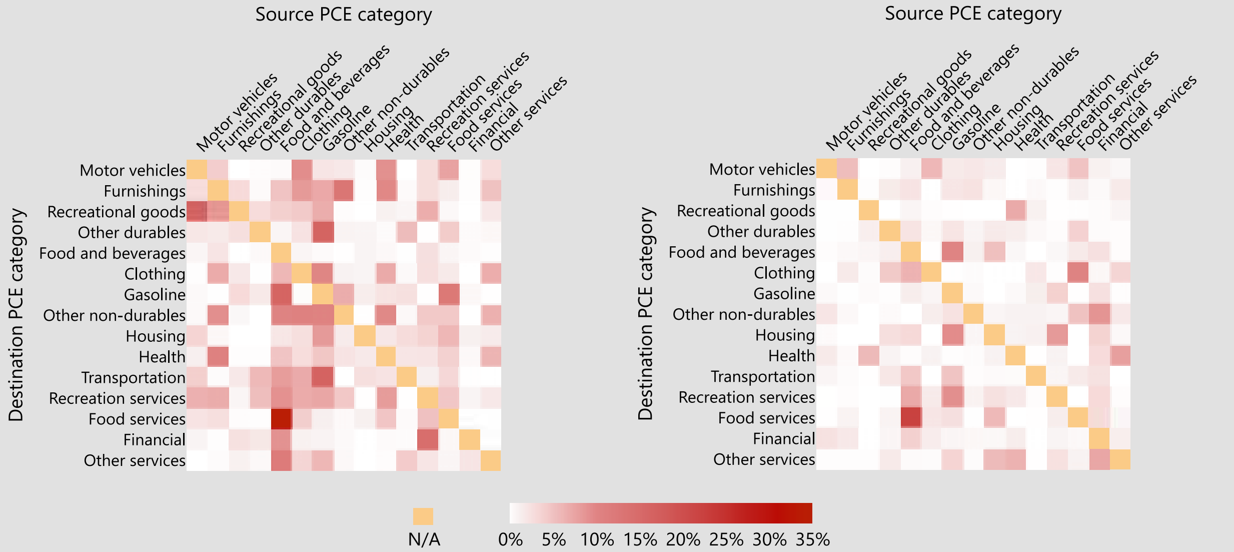
By summing the elements of the variance decomposition in Graph A1 by column and by row, respectively, one obtains a measure of the extent of spillovers "exported to" and "imported from" each of the different sectors. These are visualised in Graph A2. Comparing directional spillovers across sectors between high- and low-inflation regimes indicates that they have diminished and have become more concentrated in a few sectors that remain strong exporters of spillovers, such as food and gasoline. This highlights their centrality in driving overall price developments. In line with the finding that total spillovers are lower in a low-inflation

Bilateral price spillovers across US PCE categories[1]

Graph A1

A. Sample period: January 1965–December 1985

B. Sample period: January 1986–December 2019

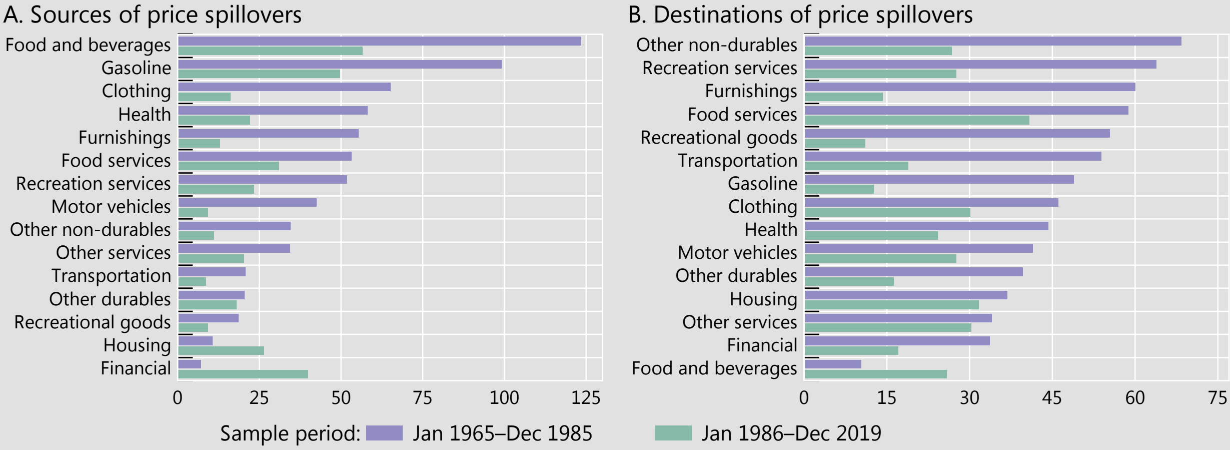


[1] Share of the variance of sectoral price changes explained by shocks to prices in other sectors over a horizon of 12 months.

Sources: Board of Governors of the Federal Reserve System; Federal Reserve Bank of St Louis, FRED; World Bank; Datastream; national data; BIS.

Directional price spillovers among main US PCE categories[1]

In per cent — Graph A2



[1] Share of the variance of sectoral price changes explained by shocks to prices in other sectors over a horizon of 12 months.

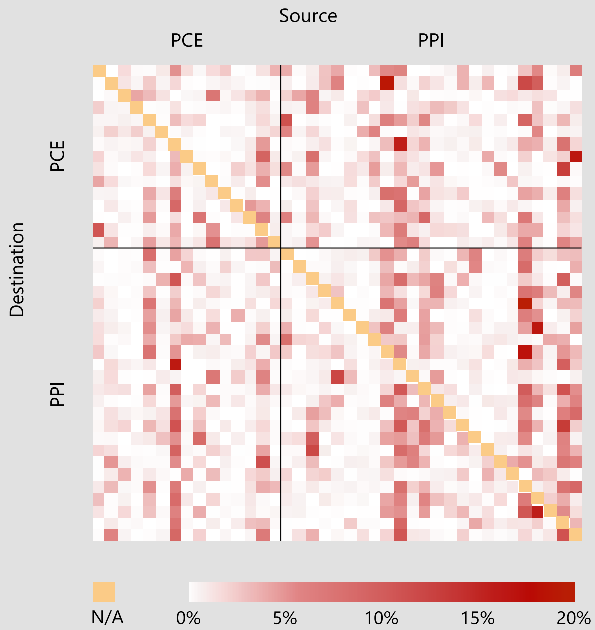
Sources: Board of Governors of the Federal Reserve System; Federal Reserve Bank of St Louis, FRED; World Bank; Datastream; national data; BIS.

regime, it is also the case that directional spillovers are smaller in the post-1986 sample. That said, there are two categories – housing and financial services – in which the size of exported spillovers has increased.

PCE measures purchases of final products and services. A natural question to ask is how price changes in items that are upstream in the value chain, which constitute inputs to the production of final goods and services, transmit downstream. This can be answered by including PPI sub-indices in the analysis and constructing a larger matrix of contributions to the variance.

How price spillovers percolate downstream[1]

Graph A3



[1] Share of the variance of sectoral price changes explained by shocks to prices in other sectors over a horizon of 12 months. See technical annex for details.

Sources: Board of Governors of the Federal Reserve System; Federal Reserve Bank of St Louis, FRED; World Bank; Datastream; national data; BIS.

The results are presented in Graph A3. The GFEVD matrix can now be divided in four blocks. The top-left block represents spillovers within PCE categories, and is conceptually the same as discussed above. The bottom-right block instead displays spillovers within PPI categories. Its generally darker shading, compared with the top-left block, indicates that spillovers among PPI components tend to be larger than those among PCE components. The other blocks represent spillovers from PPI to PCE (top right) and from PCE to PPI (bottom left). Not surprisingly, those from PPI to PCE are stronger than vice versa. Note that the columns of PPI items are ordered based on their (increasing) degree of upstreamness,[3] so that the darker shades appearing on the right side correspond to sectors further upstream, indicating that they tend to be the source of stronger system-wide spillovers.

[1] The methodology follows that proposed by Diebold and Yilmaz (2012) and Lombardi et al (2013). [2] The generalised forecast error variance decomposition is constructed by first modelling monthly growth rates in sector-level PCE deflators as a Bayesian VAR with six lags controlling for common, economy-wide explanatory factors such as economic slack, inflation expectations and oil prices. Generalised impulse responses to shocks to each of the variables are then used to construct the decomposition of forecast errors over a horizon of 12 months. For further technical details, see Lombardi and Zakrajšek (2022). [3] The index of upstreamness is computed following Antràs et al (2012).

tenable assumption in a stable inflationary environment, it can be more problematic when inflation is liable to shifts across regimes.

Wage and price formation

All this suggests that it is worth more closely examining the wage and price formation process. This can also more clearly bring out the role of inflation expectations of workers and firms.

There are many similarities in the way wages and prices adjust. First, both are sensitive to the same cyclical and structural forces. Second, their adjustment varies systematically with the level of inflation itself, helping to entrench the high- and low-inflation regimes. Finally, both are deeply influenced by inflation expectations.

These factors play somewhat different roles. Cyclical and structural forces shape the pricing power of workers and firms – in particular, firms' ability to raise prices when profit margins are squeezed and workers' ability to obtain higher wages when their purchasing power is eroded. Inflation expectations provide a key incentive to do so. And the level of inflation influences both their ability and incentives, not least because of its impact on structural features of contracting arrangements and on the sensitivity of expectations to relative price changes.

Let's consider in more detail the roles of pricing power and inflation in wage-price formation.

Pricing power

The pricing power of economic agents is ultimately determined by *perceptions* of the consequences of charging a higher price or asking for a higher wage. How will customers and employers react? How will "competitors", be these other firms or workers, respond? Will firms see their profit margins or market shares squeezed? Will workers lose their jobs? Explaining pricing power means explaining how cyclical and structural forces exert their impact on wage and price dynamics.

Cyclical forces

Cyclical forces are those that have generally attracted most attention. The main such force is *aggregate* demand pressures. When the economy is running hot, it is generally more likely for labour to have their wage demands accepted and for firms to have their customers tolerate higher prices.

Box B

The Phillips curve and inflation under the hood

The Phillips curve first emerged as an empirical relationship between wages and the level of unemployment (Phillips (1958)). Since this seminal contribution, the empirical regularity has been extended to prices (Samuelson and Solow (1960)) and further explored and broadened. It has now come to play a key role in many macroeconomic models as the main device to explain inflation.

In its simplest, prototypical version, a Phillips curve relates inflation (typically for a broad price index) to a measure of economic slack (typically the output or unemployment gap). When this reduced-form relationship is brought to the data, it turns into a linear regression in which inflation is expressed as a function of a chosen proxy for economic slack. The other elements in the model are a constant, representing the level around which inflation hovers, and residuals, capturing *temporary*, if possibly persistent, inflation deviations from their mean that are not explained by slack ("shocks"). More formally, a prototypical Phillips curve takes the following form:

$$\pi_t = c + \beta\left(y_t - \hat{y}\right) + e_t$$

Such a framework is obviously too stylised to provide a faithful representation of inflation. Thus, the most typical approach is to extend it to capture the role of expectations and relate the residuals to some key observable variables (key sources of shocks). Expectations are assumed to influence inflation directly; they can be thought of as replacing the constant, allowing it to move systematically over time. The variables included to capture prominent shocks are salient relative price changes, most often oil prices or exchange rates. The prototypical Phillips curve thus becomes:

$$\pi_t = \left(1-\alpha\right)\pi^e_{t+h} + \alpha\pi_{t-1} + \beta\left(y_t - \hat{y}\right) + \delta s_t + e_t\ ,$$

where π^e_{t+h} is a measure of inflation expectations over a certain horizon h, and s_t is a (vector of) relative price changes.

This approach is a very useful parsimonious way of capturing key relationships behind the inflation process. However, from an under the hood perspective, it misses some important elements.

Aggregation has obvious consequences.

For one, a single measure of economic slack cannot capture sectoral developments and differences in the sensitivity of prices to sectoral slack. For example, sectors may differ in their exposure to global conditions – the tradeable/non-tradeable distinction is an obvious example. And even differences across purely domestic sectors can matter, as highlighted by the post-Covid developments.

In addition, there is a lot that can be learnt about the dynamics of inflation from the behaviour of individual prices. A valuable insight is the much bigger role of (mostly transitory) idiosyncratic or relative price changes when inflation settles at a low level. The importance of secular relative price trends is another, most prominently the long-term increase in the price of non-tradeables, including many services, relative to that of tradeables, which are mainly goods.

The other implications are more closely related to the wage- and price-setting mechanisms and their interactions. These are at the very heart of the inflation process but are necessarily glossed over in the Phillips curve representation.

First, the framework considers explicitly only the cyclical forces that influence the pricing power of labour and firms, working through economic slack. As a result, it obscures the role of structural factors. Notable examples include globalisation, technology, demographics and other features of labour and product markets.

Second, inflation expectations affect inflation directly. One implication is that there is no role for attempts to recoup losses in purchasing power, or to compensate for squeezes in profit margins. In other words, unless inflation expectations adjust, bygones are bygones, so that wage-price spirals cannot occur.

Third, there is no role for shocks to feed into the wage-price process and generate permanent, or even persistent, changes in the inflation rate. For example, a large oil price increase does not directly affect economic slack, and hence the cyclical component of pricing power. Nor does it induce attempts to compensate for losses in purchasing power or squeezes in profit margins.

Finally, there is no room for the level of inflation to systematically influence its dynamics. For instance, the response of wages and prices to slack or to changes in salient prices is modelled the same way, irrespective of whether the economy is operating in a high- or low-inflation regime.

These omitted factors tend to show up as changes in equation coefficients. For instance, structural changes that diminish the sensitivity of inflation to slack (eg globalisation, technology, a weakening in workers' bargaining power), will result in a "flattening" of the Phillips curve, a well documented stylised fact.

One way of putting agents' pricing decisions centre stage is to resort to "microfounded" versions of the Phillips curve, that is, ones in which the relationship is derived directly from pricing decisions (see eg Roberts (1995)). In these models, inflation results from the optimising behaviour of individual economic agents in the presence of "nominal rigidities", ie impediments to instantaneous price adjustments. This also allows for a multiplicity of prices. These so-called "New Keynesian Phillips curves" describe a relationship between inflation, inflation expectations and marginal production costs, mc_t ie

$$\pi_t = E\left(\pi_{t+1}\right) + \kappa mc_t$$

While appealing from a theoretical standpoint, such a version of the Phillips curve suffers from serious practical shortcomings. As neither inflation expectations nor marginal costs can be directly observed, bringing a New Keynesian Phillips curve to the data requires additional assumptions. Marginal costs are typically proxied using the output or unemployment gap, or even real unit labour costs. Inflation expectations can either be estimated in a model-consistent way, or proxied using survey-based measures (eg forecasts of inflation). So, even starting from the microfounded version of the Phillips curve, a researcher typically ends up estimating a reduced-form relationship between inflation and a measure of slack that looks a lot like the prototypical version described above. Moreover, the standard version only features a bundled consumer good, and hence does not allow a role for relative price changes. And even in versions with multiple sectors, relative price changes only reflect different adjustment speeds in prices, so that longer-run trends play no role.

That said, sectoral demand pressures, and differences across them, also matter. Whenever sectoral imbalances take centre stage, aggregate measures of slack are an insufficient indicator of the impact of cyclical factors on inflation. Given differences in the strength of sectoral forces and in the response of prices to those forces, a given measure of aggregate demand may be associated with quite different inflationary pressures.

Probably the most important distinction in this context is the one between tradeables and non-tradeables – one that has a long tradition in economics. Tradeable prices are more directly exposed to external factors, including international demand and supply imbalances and global financial conditions; non-tradeable prices are more sensitive to domestic conditions.[11] Of course, domestic demand conditions affect the exchange rate, and hence have an important indirect impact on the prices of tradeables.

The implication is that, as countries have become more open over time because of globalisation, one would expect their inflation rates to have become more sensitive to cyclical global factors as well.[12] For individual countries, these forces may show up as changes in *relative* prices, especially those of commodities. Since these are often treated as "supply shocks", there can be a tendency to underestimate the role of aggregate demand in inflation whenever these pressures affect several countries simultaneously.[13]

But the impact of the distinction between tradeables and non-tradeables goes further. Just as in the domestic context, supply chains can act as a transmission channel of global sectoral forces and facilitate their propagation. For instance, there is evidence that the exposure of countries to global value chains helps explain the relative importance of domestic and (suitably weighted) global measures of economic slack, both across countries and over time.[14]

Furthermore, sectoral factors, domestic and global, can interact. Their interaction has been very much in evidence in the unexpected recent flare-up in inflation (Chapter I). The pandemic has induced a surprisingly persistent rotation from services to goods, and the prices of many commodities have reflected global demand pressures and dislocations in global value chains ("bottlenecks"), which have made it harder for supply to keep up with the strong rebound in demand.

Structural forces

Structural forces have a major influence on wage- and price-setting. The previous discussion highlights one channel through which they can influence the sensitivity of inflation to domestic demand pressures, ie the openness of the economy. But there are other examples, including structural features that may hinder the reallocation of labour across sectors (eg the design of the pension system or unemployment benefits).

The evolution of labour markets vividly illustrates how broad and deep the influence of structural forces can be. Labour markets have seen major structural changes since the Great Inflation of the 1970s. Their net effect has been to reduce the pricing power of labour. This secular decline reflects many factors, including a declining role of the public sector in setting wages; dwindling unionisation; a wave of labour market deregulation; the gradual opening of markets due to globalisation; and demographics. For instance, it is hard to imagine that the bargaining power of labour, especially in advanced economies, could have remained immune to the entry of large numbers of (predominantly low-wage) workers into the the global trading system. China and former members of the Soviet bloc are the most prominent examples. A quickening of technological change is yet another possible factor, in this case increasing the competition between labour and capital.

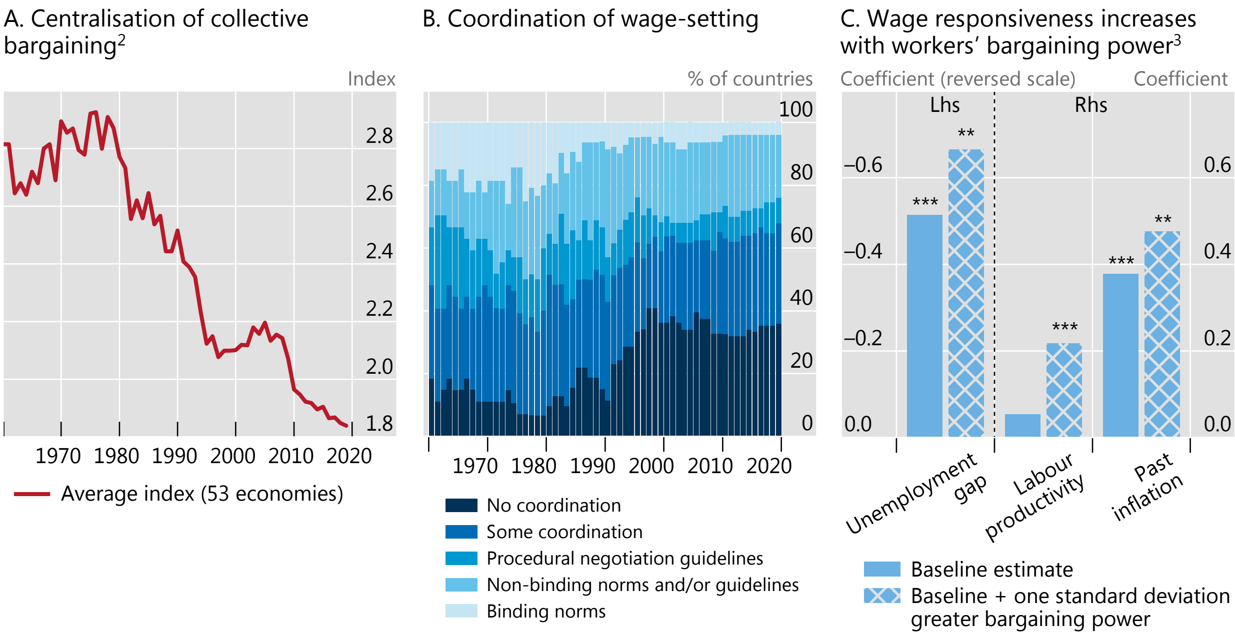
Measuring pricing power is not straightforward. For example, it may not be the actual entry of firms that determines their pricing power but the threat of entry ("contestability"). Similarly, the actual extent to which jobs are relocated to foreign countries may be less important than the threat thereof.

Again, labour markets can help illustrate the point. One possible, albeit imperfect, indicator of labour's decreasing structural pricing power is the secular decline in the degree of centralisation of wage negotiations (Graph 5.A). Another is the reduction in the number of countries adopting binding norms in the coordination of wage-setting (Graph 5.B).

Based on these indicators, there is indeed evidence that workers' bargaining power is important in shaping the response of wages to both prices and economic

Institutional features play a key role in the wage-setting process[1]

Graph 5



[1] See technical annex for details. [2] Higher values indicate higher degree of centralisation. [3] ***/** indicates statistical significance at the 1%/5% level. For the cross-hatched bars, statistical significance refers to the incremental effect of a change in bargaining power.

Sources: OECD; OECD/AIAS ICTWSS database; BIS.

slack (Graph 5.C). When workers' bargaining power is high, the cyclical sensitivity of inflation to the unemployment gap increases, reflecting greater pricing power for any given degree of tightness in labour markets.[15] Moreover, workers are better placed to successfully negotiate higher wages to reap the benefits of increases in labour productivity as well as to recoup losses in purchasing power due to past inflation.

The inflation environment

In addition to cyclical and structural factors, the level of inflation itself can influence wage- and price-setting and hence the likelihood and intensity of wage-price spirals. In general, a high-inflation regime, if it persists, induces behavioural changes which raise the probability that it will become entrenched, not least by amplifying the impact of relative price increases. Several mechanisms are at work.

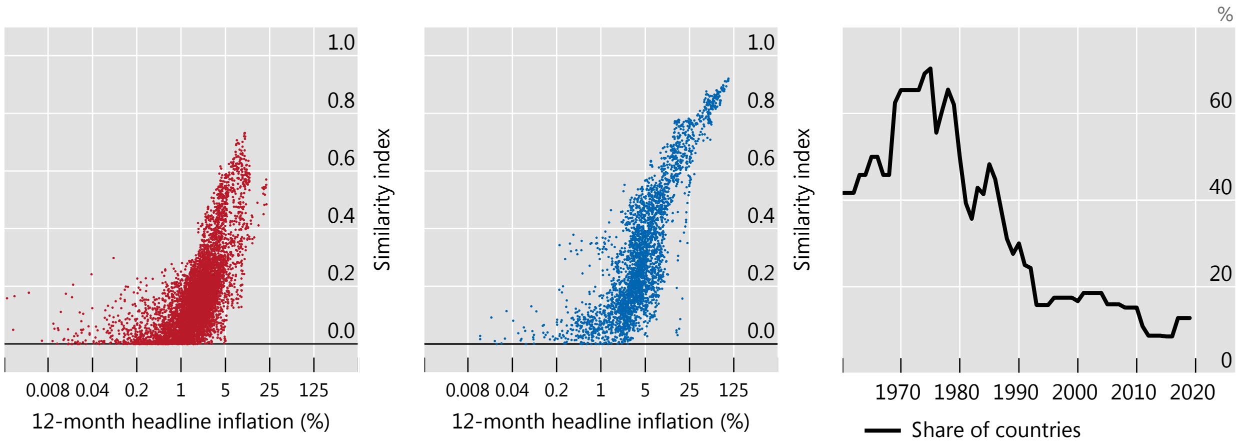
First and foremost, when inflation is very low, it may cease to be a significant factor influencing economic decisions. After all, agents' bandwidth is limited and acquiring information is costly – leading to so-called "rational inattention".[16] Indeed, this is the very definition that Paul Volcker, and later Alan Greenspan, gave of price stability: "a situation in which expectations of generally rising (or falling) prices over a considerable period are not a pervasive influence on economic and financial behavior."[17]

Second, and closely related, it stands to reason that the degree to which the *general* price level becomes relevant for *individual* decisions increases with the level of inflation. When inflation rises, price changes become more similar (Graphs 6.A and 6.B). As a result, differences in consumption patterns matter less. After all, wage earners do not care about the general price level per se, but only about their own cost of living. Similarly, firms care about the general price level only insofar as it carries information about how competitors might react or about their own costs. Since wages, in turn, are an essential component of costs, the stronger link of wages to general prices reinforces the relevance of inflation for firm decisions, and vice versa.

Third, the level of inflation is bound to influence the importance of inflation expectations. Once the general price level becomes a focus of attention, workers and

When inflation is high, it becomes a coordinating device in pricing decisions[1] — Graph 6

A. Similarity of price changes in AEs — B. Similarity of price changes in EMEs — C. Price indexation in wage contracts



[1] See technical annex for details.

Sources: OECD/AIAS ICTWSS database; CEIC; national data; BIS.

firms will initially try to make up for the erosion of purchasing power or profit margins that they have *already* incurred. This, in and of itself, could trigger wage-price spirals if background conditions are sufficiently favourable. And, once inflation becomes sufficiently high and is expected to persist, they will also try to anticipate *future* changes in the general price level, as these will erode purchasing power and profit margins before contracts can be renegotiated.[18]

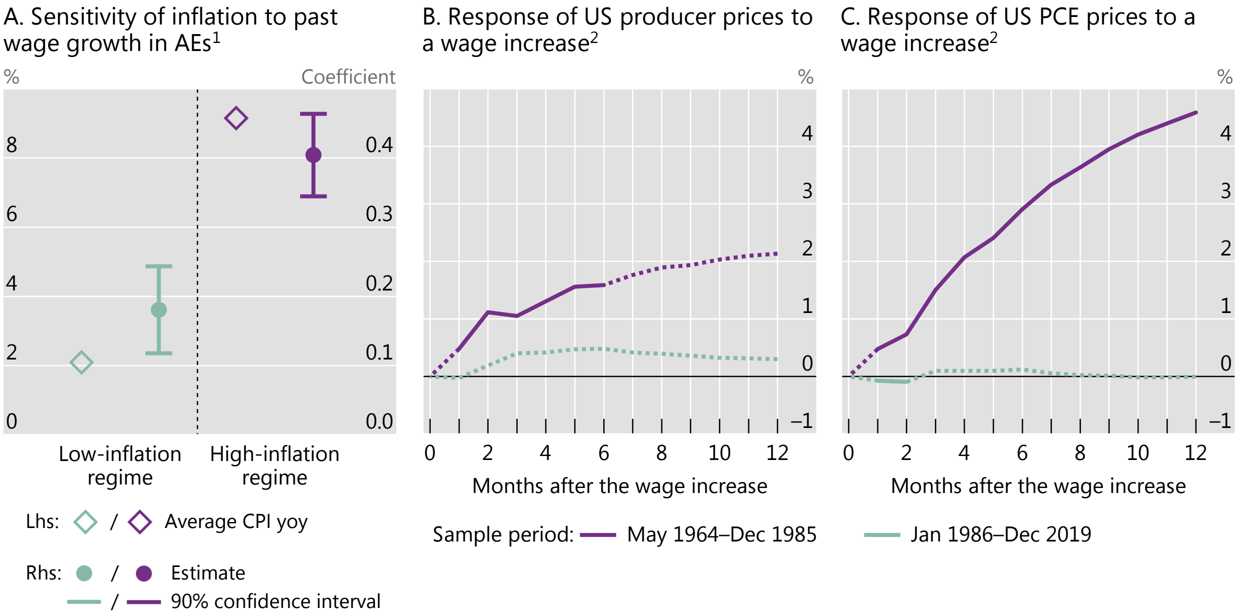
Fourth, if sufficiently high and persistent, inflation will influence the *structural* features of wage- and price-setting. The higher the inflation rate, the greater the incentive for workers to unionise, and for wage negotiations to be centralised, as the inflation rate acts as a stronger focal point.[19] And, the more persistent the inflation rate, the greater the incentive to index wages and, more generally, to reduce the length of contracts that are fixed in nominal terms.[20] These forces are amplified by the stylised fact that higher inflation rates tend to go hand in hand with higher volatility and hence uncertainty.

There is considerable evidence supporting the impact of the inflation regime on contractual arrangements.[21] For instance, indexation practices tend to be more prevalent in countries with a higher inflation history (eg in EMEs in Latin America relative to those in Asia). And reliance on indexation has declined along with the inflation rate (Graph 6.C).[22] In other words, since the 1980s, structural forces *and* a decline in inflation itself have arguably reinforced each other in reducing the bargaining power of labour.

It is not hard to find the footprint of inflation regimes on wage- and price-setting.

Consider price-setting first. As one example, across countries, the pass-through from wages to inflation becomes more muted at lower inflation rates (Graph 7.A). This finding is corroborated by US-specific evidence: unanticipated changes in wages estimated over a sample starting in 1986 transmit less to both the producer

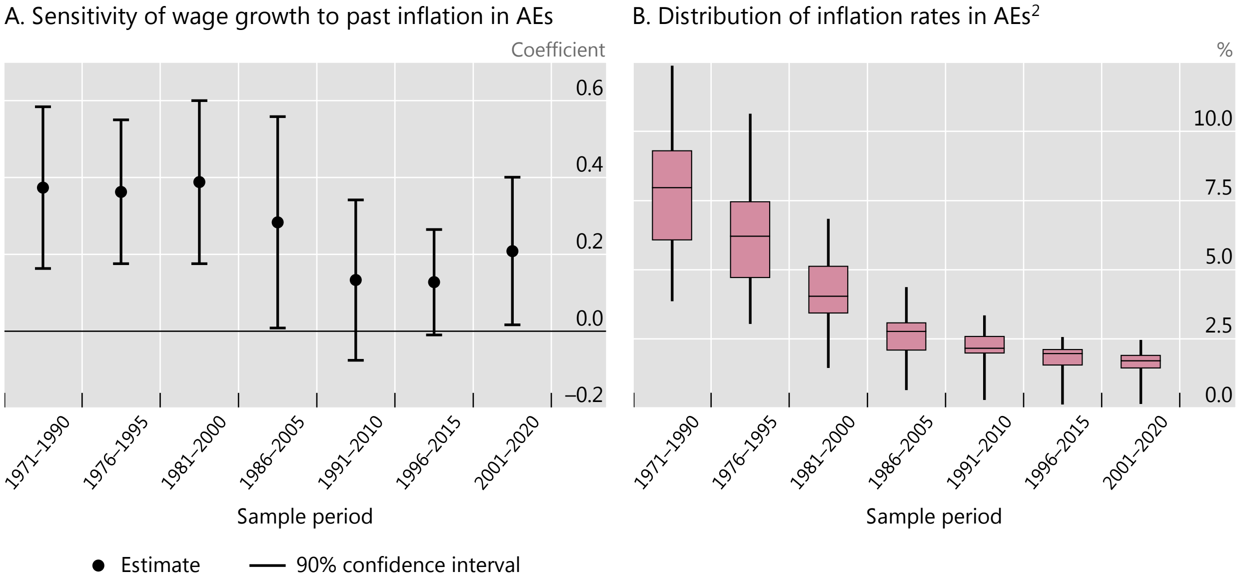
The pass-through of wages to inflation is weaker in low-inflation regimes — Graph 7



[1] See technical annex for details, including regime dates. [2] The estimated impact of a 5% unanticipated increase in nominal wages in month 0 on the specified US price index. The solid lines indicate portions of the response that are statistically significant at the 10% level.

Sources: Federal Reserve Bank of St Louis, FRED; OECD; Datastream; national data; BIS.

Wages have become less sensitive to inflation[1] Graph 8



[1] See technical annex for details. [2] Box plots show median, minimum, maximum and interquartile range of year-on-year headline inflation.

Sources: OECD; national data; BIS.

and consumer price indexes than they did in the preceding high-inflation regime (Graphs 7.B and 7.C).

Similarly, wages have become less responsive to inflation over time. For instance, corroborating evidence emerges from a simple empirical model in which wage growth is a function of past inflation, the unemployment gap and labour productivity growth estimated on a panel of advanced economies. Past inflation has become less reflected in wage gains (Graph 8.A) as its average level has declined over time (Graph 8.B).

Putting these various pieces of evidence together suggests that the link between wages and prices has become looser. A statistical exercise that captures their joint dynamics illustrates the point. When wages, say, fall behind their long-term relationship with prices, they tend to subsequently catch up, although more slowly in the low-inflation regime (Graph 9.A). The same holds for prices (Graph 9.B).

Taken together, all these findings may help explain why high- and low-inflation regimes are self-reinforcing. This is largely through their impact on wage and price adjustments and hence on the likelihood and intensity of wage-price spirals. In a low-inflation regime, both the inflation rate and individual price changes are less noticeable and the general price level is less representative of the prices that matter for individual agents. Further, inflation expectations play a smaller role, and inflation induces changes in structural features of wage- and price-setting that help keep it low. High-inflation regimes are the mirror image.

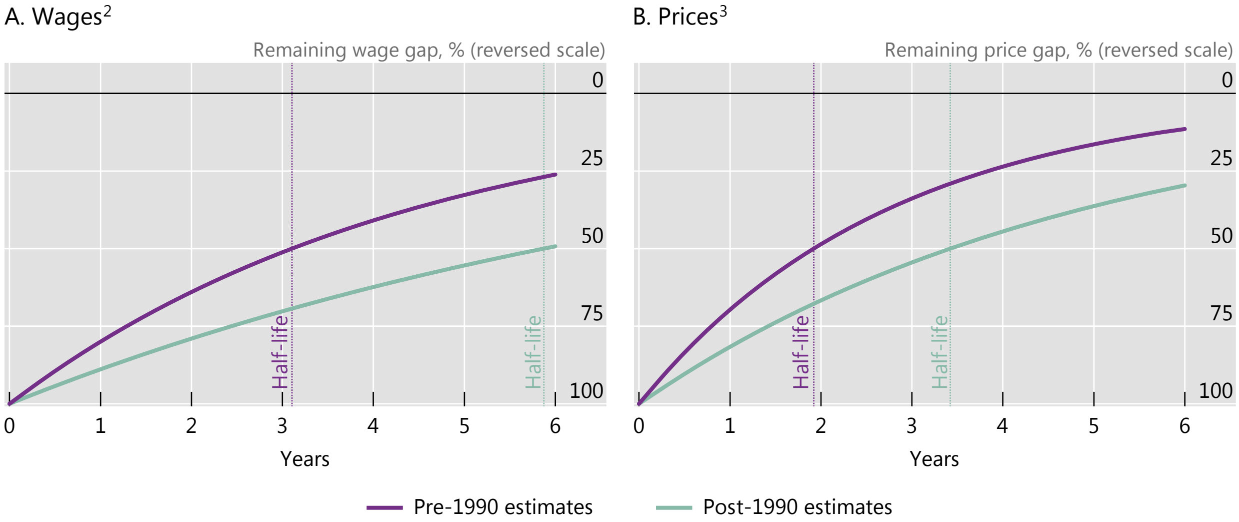
Inflation expectations in financial markets

While the expectations of firms and households directly affect price- and wage-setting, those in financial markets play an important indirect role through a variety of channels.

First, they influence financial conditions and hence aggregate demand. A key factor behind any decision to borrow or save is the interest rate, ie the amount the

Wage and price reactions to past shortfalls have become slower[1]

Graph 9



[1] The half-life is the time taken for half of the wage or price gap to have closed; see technical annex for further details. [2] Response of nominal wages when real wages fall in year zero. [3] Response of the price index when real wages rise in year zero.

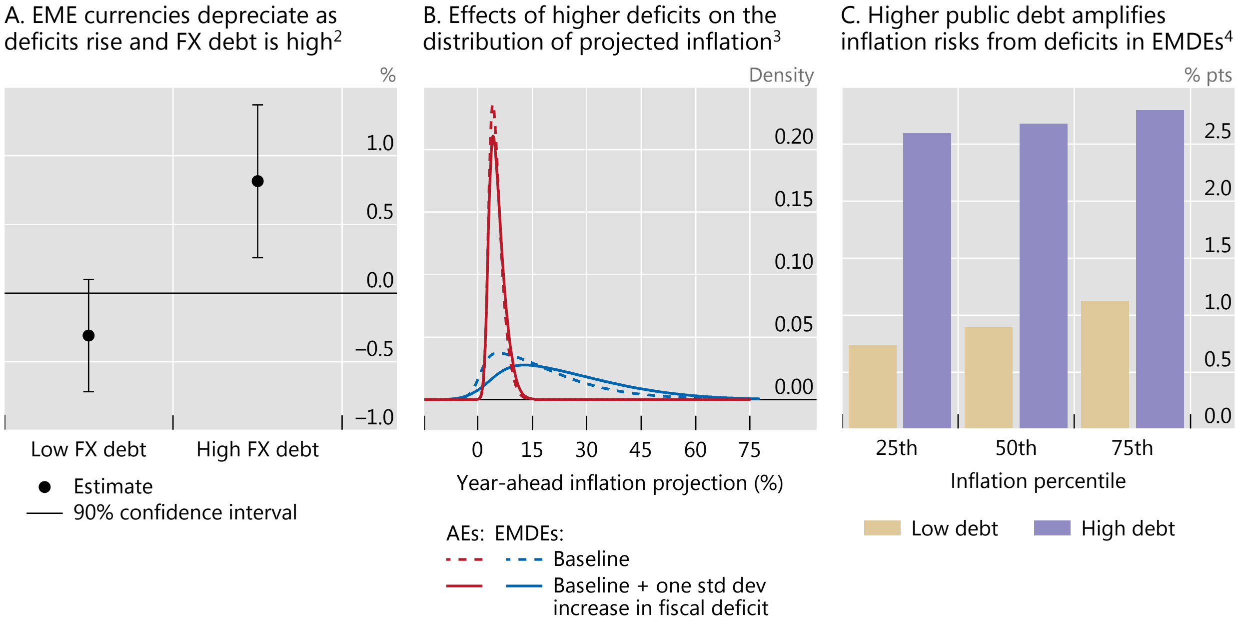
Sources: OECD; national data; BIS.

borrower will need to pay to service their debt and the return to the saver for postponing consumption. Apart from the short-term policy rate, which is set by the central bank, the inflation expectations of market participants help determine nominal interest rates at longer maturities, as investors need to be compensated for the expected erosion of their purchasing power. In turn, expenditures are shaped partly by nominal rates, which have a first-order impact on cash flows, and by inflation-adjusted ("real") interest rates, which reflect the real value of the resources transferred over time. Long-term mortgage rates are a good example.

Second, through their impact on interest rates, the inflation expectations embedded in financial markets have a major effect on the exchange rate – probably the most salient and important relative price for open economies. This is because they affect the returns across currencies, and hence the investment and borrowing decisions of market participants that have access to both domestic and foreign funds. These decisions will, in turn, be an important driver of exchange rates, as sudden capital outflows can trigger large depreciations. Moreover, through exchange rates, inflation expectations also affect the value of both assets and debts denominated in foreign currencies. This is especially important in EMEs, where the use of a foreign currency to denominate contracts can be common and where currency mismatches – discrepancies between the currency denominations of assets and liabilities – can be widespread.[23]

The impact on the servicing costs and debt burden of the government is especially important. One possible mechanism is through financial market perceptions of the sustainability of fiscal positions. For instance, there is evidence from EMEs that when the share of public debt denominated in foreign currency is high, an increase in the fiscal deficit results in a depreciation of the currency (Graph 10.A). This depreciation is one reason why deficits, more generally, shift the whole distribution of future inflation outcomes, increasing the likelihood of higher inflation (Graph 10.B). This effect is stronger in EMEs, where debt sustainability tends to be more of a challenge and the exchange rate plays a bigger role. The effect of deficits on inflation is also bigger where debt levels are higher (Graph 10.C).

Higher fiscal deficits boost inflation risks in EMEs[1] Graph 10



[1] See technical annex for details. [2] The effect of a 1 percentage point increase in the fiscal deficit on the depreciation of the EME currency against the US dollar in the following year. [3] Change in one-year-ahead conditional inflation forecast distribution (change from dashed to solid) when there is a one standard deviation increase in fiscal deficit. [4] The effect of a 1 percentage point increase in the fiscal deficit on annualised EMDE inflation over the next two years.

Sources: Banerjee et al (2020); BIS.

Third, financial markets' inflation expectations are useful in and of themselves. While they may not be a good proxy for the expectations of wage- and price-setters, they can help forecast inflation. After all, they aggregate the information of a myriad of investors, who "put their money where their mouths are". Moreover, their timeliness can be of great value. And so is the fact that, through option prices, it is possible to tease out information about the perceived risks around the average or most likely future outcomes. To be sure, extracting inflation expectations from asset prices is not without pitfalls. Since expectations are not observable, some "model" is necessary to estimate them. Moreover, they are "contaminated" by the compensation investors require for bearing inflation risk as well as by market characteristics, including the underlying liquidity. Even so, at the end of the day, what matters is their predictive content.

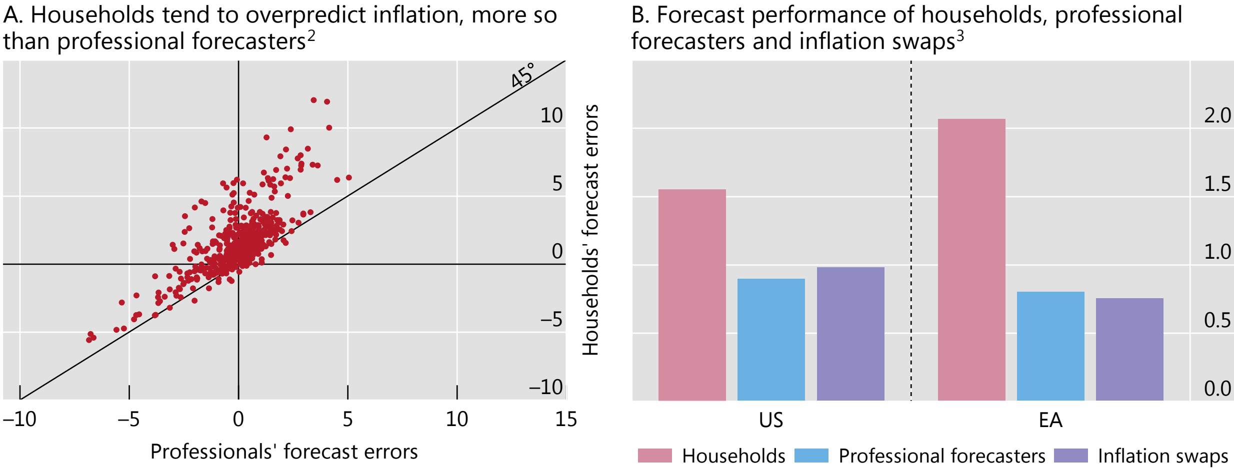
The empirical evidence indicates that financial market measures of inflation expectations can indeed be valuable. While household expectations tend to be biased on the upside when compared with those made by professional forecasters (Graph 11.A), financial market expectations perform relatively well (Graph 11.B). They also have the advantage of timeliness: in contrast to surveys that generally take place regularly at fixed intervals, financial market expectations can be monitored in real time. As such, they may prove especially useful when economic conditions change rapidly.

The timeliness of market-based inflation expectations is one reason why they are useful to central banks when setting monetary policy. As such, they serve not only as indicators of the future path of inflation, but also as real-time gauges of the credibility of the central bank's commitment to price stability. Their use in this context provides a valuable additional piece of information, although it needs to be managed properly (see below).

Near-term inflation forecast performance[1]

In percentage points

Graph 11



[1] See technical annex for details. [2] Difference between one-year-ahead inflation expectations of households or professional forecasters and realised inflation. [3] Root mean squared errors of one-year-ahead inflation forecasts.

Sources: Bloomberg; Consensus Economics; Datastream; national consumer surveys; national data; BIS.

The role of monetary policy

The imprint of monetary policy on inflation can be easily traced through history. It can be found in the relative stability of the price level under the Gold Standard, the costly deflation of the Great Depression, the occasional hyperinflations, the Great Inflation of the 1970s under a fiat standard and the subsequent Great Disinflation from the 1990s. This phase ushered in a long period of low and stable inflation, as central banks gave clear priority to inflation control – the era of inflation targeting.

Monetary policy influences inflation in two ways.

First, through the policy regime, ie the rules of the game that define the monetary policy framework itself. These include the relative weight of different objectives; the core features of the systematic policy response to the evolution of the economy (the central bank's "reaction function"); the tools employed; transparency, accountability and, most importantly, the degree of autonomy ("independence") from the government, which offers insulation from short-term political pressures. These features ultimately determine the central bank's credibility and ability to deliver on its objectives. The conjunction of inflation targeting with central bank independence is the most recent and widespread example of such a framework. It is the monetary policy framework that has the biggest influence on inflation expectations as well as on the features of wage and price formation.

Second, through changes in the monetary policy stance *within* a regime. These operate mainly through aggregate demand in the economy. It is through changes in the stance that the central bank calibrates the degree of accommodation or tightness to steer economic activity, and hence inflation. These adjustments help fine-tune the systematic policy response and its flexibility to evolving circumstances, sometimes requiring significant departures from the typical reaction function.

What light can the under the hood perspective shed on these issues? Consider, in turn, the operation of monetary policy in a low-inflation rate regime and transitions to a higher one.

Box C

Comparing different measures of inflation

Measuring inflation involves a balancing act between constructing a useful guidepost to assess price stability (and hence inform central banks' decisions) and identifying an index that is comprehensive, transparent and easy to communicate to the public, whose experience of price changes it should duly reflect. Most price indices are indeed based on the prices of goods and services in a typical consumption basket of a median household. As such, they reflect the cost of consumption, rather than the cost of living per se.[1]

Central banks look at price indices partly to extract signals about imbalances between aggregate demand and supply capacity that might require a monetary policy response. In addition, persistent movements in price levels can serve as a warning indicator that inflation expectations may be at risk of de-anchoring. Yet, as argued in the chapter, price indices mechanically reflect all price changes, including those that have limited predictive value for future inflation, or are not influenced by monetary policy.[2] In principle, monetary authorities would like to react differently to different types of price change.

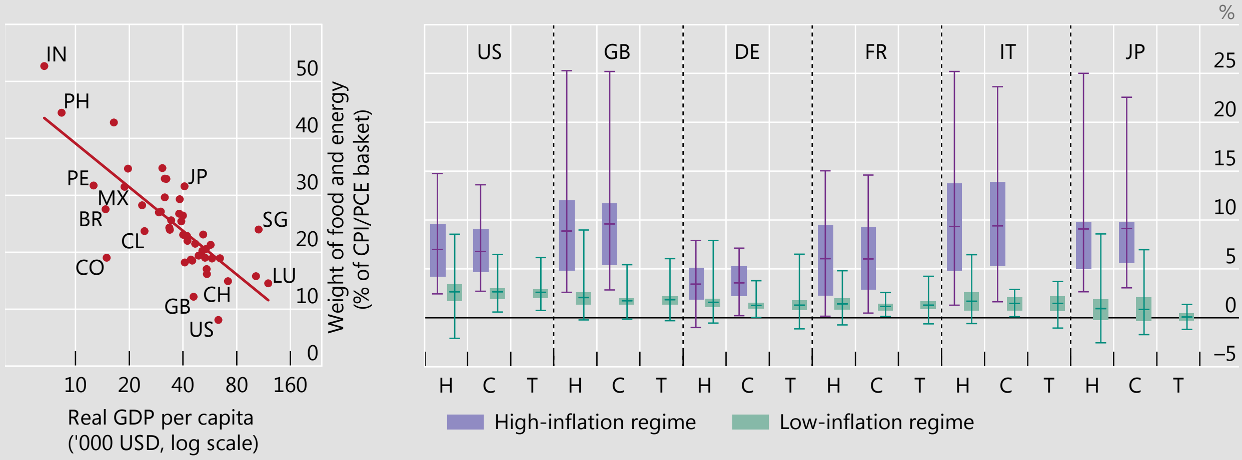
Some prices are particularly volatile and hence liable to be misleading. This happens for goods that are more subject to large exogenous shocks, for example energy prices (eg due to conflicts or disruptions) and food (subject to weather events and seasonality). These make up a particularly large share of overall consumption, especially in some emerging market economies (Graph C1.A). One way to minimise their impact on inflation is to rely on measures of "core" inflation that reduce the effect of specific components, by excluding categories like food and energy that tend to be exogenously driven. Another is to rely on trimmed measures that drop the most volatile components at each point in time, irrespective of their source.

CPI weights on food and energy and different measures of inflation[1]

Graph C1

A. Food and energy have high weights in CPI in some economies[2]

B. Different measures of inflation for selected economies[3]



C = core; H = headline; T = trimmed.

[1] See Technical Annex for details. [2] For US, weights are based on personal consumption expenditure. [3] Box plots show median, minimum, maximum and interquartile range of year-on-year headline inflation.

Sources: Bank of Japan; IMF; Datastream; national data; BIS.

The distribution of inflation outcomes, however measured, becomes much more concentrated around low values when inflation is firmly in control of central banks (Graph C1.B). Under high-inflation regimes, both core and headline inflation appear very volatile, while in a low-inflation regime core inflation tends to be more stable, as one would expect.

[1] A notable exception is the US Personal Consumption Expenditure (PCE) deflator. [2] Prices administered by government agencies are an important source of prices not affected by monetary policy in some economies.

Monetary policy in a low-inflation regime

The dynamics of prices in a low-inflation regime offer considerable flexibility to the central bank. In such a regime, inflation has valuable self-equilibrating properties. Its evolution largely reflects changes in sector-specific, relative prices that are, for the most part, transitory. Because of the lack of frequent and persistent salient price changes that could drive inflation durably higher, agents need not pay much attention to inflation. Partly as a result, wages and prices do not tend to chase each other higher. Flexibility in this context could mean greater tolerance for moderate, even if persistent, deviations of inflation from narrowly defined targets. It is as if, having succeeded in bringing inflation under control, the central bank can enjoy the fruits of its hard-earned credibility.

A low-inflation regime also confers flexibility regarding the specific measure of inflation that the central bank can target. In an environment in which relative price changes are dominant, and possibly disconnected from the dynamics of underlying inflation, there is a premium on measures that abstract, to the extent possible, from the most volatile relative price changes (see Box C for a detailed discussion).

There are good reasons for the central bank to make use of flexibility. For one, with inflation low, supply side forces driving price changes become relatively more important. These forces reflect natural adjustments in the economy that monetary policy should accommodate, unless they threaten the low-inflation regime itself. In addition, the evidence suggests that it becomes difficult for monetary policy to steer inflation precisely. This, in turn, increases the possible costs of trying.

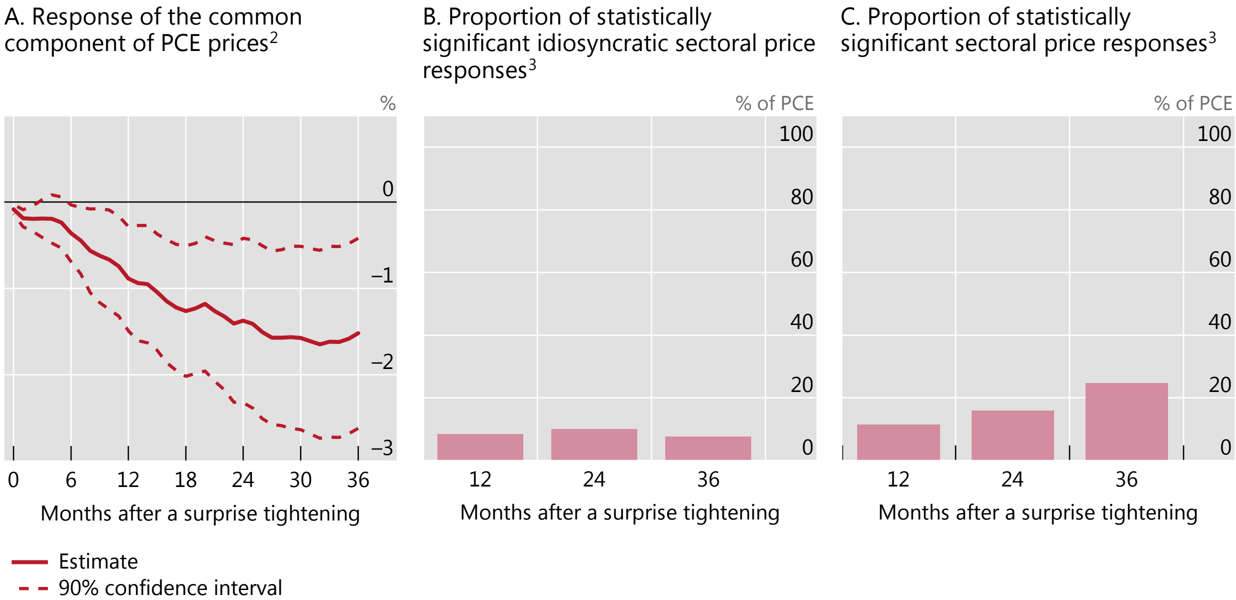
One reason behind the difficulties in steering inflation reflects the very nature of the price changes. One would expect monetary policy to operate through the common component of inflation, which tends to reflect the driver common to all price changes. Empirical evidence supports this conjecture. Changes in the policy stance have a persistent impact on the common component of price changes but have little impact on idiosyncratic elements in US data (Graphs 12.A and 12.B). Thus, as the common component declines relative to the sector-specific one when inflation settles at a low level, the traction of changes in the policy stance declines with it.

In addition, the evidence suggests that, at least when inflation is low, monetary policy operates through a rather narrow set of prices. The results of an exercise on US data indicate that its impact is statistically different from zero for only around one third of sectors, even after three years (Graph 12.C). Not surprisingly perhaps, the prices that exhibit a response are mainly in the cyclically sensitive services subsectors, which are more affected by domestic than foreign demand.[24]

Another piece of corroborating evidence is that monetary policy loses traction when nominal interest rates are very low.[25] Because nominal interest rates and inflation rates tend to move together, this implies more limited monetary policy traction in low-inflation regimes. This loss of traction holds even after filtering out the influence of other factors – the state of the economy, the level of debt and the apparent trend decline in "equilibrium" real interest rates. Moreover, the effect tends to intensify the longer interest rates remain low.[26]

The more limited traction of monetary policy at low levels of inflation means that bigger moves in the policy instrument are needed to produce the same inflationary effect, with larger side effects for the real economy. This has been in evidence in the post-Great Financial Crisis period, during which central banks have faced difficulties in lifting inflation back to target, partly owing to the structural disinflationary forces at play. Hence the need to keep an exceptionally easy policy stance for exceptionally long – the so-called low-for-long phenomenon. This has been one factor behind the build-up in risk-taking and financial vulnerabilities (Chapter I).

US monetary policy works mainly through the common component of inflation[1] Graph 12



[1] Responses to a surprise policy tightening of 25 basis points. See technical annex for details. [2] Including 131 narrowly defined personal consumption expenditure (PCE) sectors. [3] Significant at 10% level.

Sources: Board of Governors of the Federal Reserve System; national data; BIS.

Transitions across inflation regimes

What about transitions across regimes?

Bringing inflation under control has generally proven costly. And the higher and more entrenched the initial inflation rate, and hence the larger the required disinflation, the greater the cost is likely to be. As the previous analysis indicates, once wage-price spirals set in, they develop an inertia that is not easy to break. Expectations of persistent inflation become embedded in labour contracts and wage negotiations, requiring a larger reduction in aggregate demand, and hence higher unemployment, to break the back of persistent inflation. Monetary policy's task becomes much harder. This is true not only from a technical standpoint, but also from a political one. A broad political consensus that inflation must be brought back under control would greatly help the central bank's task. For example, it could be instrumental in inducing trade unions to accept the abandonment of indexation clauses, as it did in the 1980s.[27] But this consensus may take time to form and, in the meantime, central bank actions will inflict necessary near-term costs on the economy.

Thus, a key challenge for the central bank is to avoid transitions from low- to high-inflation regimes in the first place – to nip inflation in the bud. To be sure, a low-inflation regime has some self-equilibrating properties, which allow a credible central bank to enjoy a considerable degree of flexibility. But, if the system is subjected to too much pressure, those properties vanish. The Great Inflation of the 1970s is a case in point. This historical phase was preceded by several years of moderately high inflation, which left the inflation regime vulnerable to the 1973 oil price shock.[28] Once the oil price soared, inflation accelerated and entrenched the transition.

A tough test central banks face in this context is how to identify transitions sufficiently promptly and reliably and then to calibrate policy accordingly. Both tasks are clouded in uncertainty. The under the hood perspective sheds light on these challenges and points to ways in which they may be addressed. Ultimately, though, central banks have little choice but to consider the broadest set of information possible, both hard and soft, and form a judgment about the risks ahead. The current environment helps illustrate some of these difficulties.[29]

A first warning indicator is large and persistent changes in salient relative prices, such as those of energy and food. Large exchange rate depreciations play a similar role. For instance, recently the war in Ukraine has triggered major increases in the prices of energy and food, adding to previous upward pressures, in part related to the broader rebound in global demand (Chapter I). To be sure, such price increases are neither necessary nor sufficient to trigger a transition. But they do test the self-equilibrating properties of the system and require special attention.

A common practice to deal with such price shifts is to exclude them from the measures of underlying or core inflation, because of their high volatility. The idea is to capture only the more long-lasting influence of the inflation path. One possible drawback, however, is that it may take time for their effect to filter through.

The under the hood perspective suggests another, complementary approach: looking more closely at the degree of commonality across all price changes. A simple such indicator is the degree of spillovers across sectors based on rolling windows. Adding just a few post-Covid observations to the long estimation period indicates that spillovers have increased in several countries in the sample (Graph 13.A). A more timely indicator, which does not require long estimation windows, is an index of similarity of price changes across sectors. This measure reinforces the previous message: monthly observations point to an increase in similarity since mid-2021 (Graph 13.B).

A limitation of all such indicators is that they cover only short horizons and that the underlying changes may not be long-lasting. A complementary approach, therefore, is to consider inflation expectations. These provide a better sense of the possible evolution of inflation at different horizons, at least as perceived by economic agents. That said, as noted earlier, these indicators are not foolproof either. Expectations of economic analysts may provide little information over and above central banks' own forecasts. Those of financial market participants may also be excessively influenced by the central bank's own assessments and credibility – in these cases, they could even lull the central bank into a false sense of security.[30] And those of households and firms tend to be very backward-looking. In the current context, these indicators point to significant risks (Chapter I).

Econometric models, not least those based on stylised relationships like the standard Phillips curve, are the main tool to make longer-term forecasts, beyond one year. But they can only go so far. The reason is that they are less well equipped to address turning points (Box B). In part, this is because they tend to assume that relative price shocks, even if large, have only a temporary impact on inflation. Additionally, they may have been estimated over a long, low-inflation regime. More generally, it is because they have a hard time capturing the specific inflation dynamics during transitions, in which the level of inflation itself can alter well established relationships.

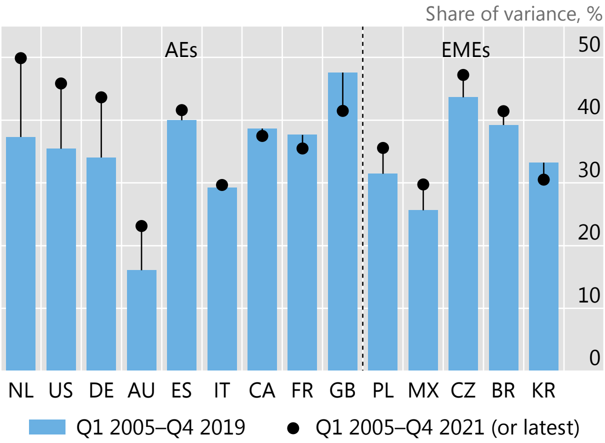
Ultimately, the most reliable warning indicator is signs of second-round effects, with wages responding to price pressures, and vice versa. These can be especially worrying if they go hand in hand with incipient changes in inflation psychology. Examples include demands for greater centralisation of wage negotiations or indexation clauses, or surveys indicating that firms have regained pricing power, as part of broader changes in the competitive environment, as observed in some countries recently (Chapter I).

This gives rise to a dilemma. Central banks may wish to wait to obtain the most reliable signals and to avoid overreacting. But waiting until signals are unequivocal

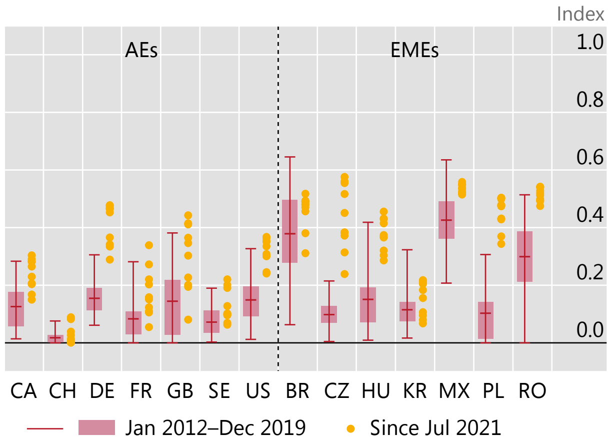
Signs of low-inflation regimes being tested

Graph 13

A. Sectoral price spillovers have generally increased…[1]



B. …and sectoral price changes have become more similar[2]



[1] Share of the variance of sectoral price changes explained by shocks to prices in other sectors over a horizon of 12 months. See Box A for details. [2] Box plots show mean, minimum, maximum and interquartile range. See technical annex for details.

Sources: Board of Governors of the Federal Reserve System; Federal Reserve Bank of St Louis, FRED; OECD; World Bank; CEIC; Datastream; national data; BIS.

heightens the risk that inflation will become entrenched, and the system will reach a tipping point. This is particularly important given that monetary policy affects inflation only with a lag. Thus the risk of waiting too long should not be underestimated, especially after a prolonged period in a low-inflation regime. If the central bank has not had to tighten significantly for a long time, it will be more uncertain about the impact of the removal of accommodation. All the more so if, in the meantime, there have been signs of aggressive risk-taking and debt has built up, not least reflecting the very low interest rates that may go hand in hand with a low-inflation regime. These challenges loom large in the current environment.

In fact, transitions may be reliably identified only ex post. Central banks, however, have no such luxury. This puts a premium on flexibility and timeliness. When faced with high risks of a transition from a low- to a high-inflation regime, the costs of falling behind the curve are likely to be high.

In considering these risks, country-specific features and circumstances are important. For structural reasons, some countries are more vulnerable than others to drifting from a low- to a high-inflation regime. The previous analysis points to several relevant features. A large weighting of salient items in the consumption basket can make increases in the inflation rate more likely to stick. Weak public finances and large currency mismatches, especially in more open economies, can make the exchange rate more sensitive to deteriorating conditions and amplify the damage a depreciation can inflict. Formal or informal wage indexation practices, and centralised bargaining, can make it easier for wage increases to recoup losses in purchasing power. Above all, a history of high inflation could increase the likelihood that inflation expectations will become unanchored, inducing broader behavioural adjustments. The actions of those in financial markets could quickly push the system beyond the point of no return. This suggests that, in economies with such features, there is a premium on a prompt monetary policy response. EMEs are more likely to fall into this category. Not surprisingly, central banks in many EMEs have responded more promptly than their AE peers to rising inflation over the past year.

The prominent role of the history of inflation in influencing transitions highlights the importance of policy frameworks and institutions. They hold the key to the credibility of monetary policy. Credibility is essential to anchor expectations firmly and, more generally, to strengthen the resilience of the economy to inflationary shocks. In this context, central bank independence is critical. It reinforces the self-equilibrating properties of a low-inflation regime, thereby granting the central bank time to assess the situation more thoroughly. And, even more importantly, it shields the institution from political economy pressures that would delay, or even prevent, the necessary remedial policy response.

Conclusion

Understanding the nature and the mechanics of the inflation process is fundamental to the conduct of monetary policy. Looking under the hood at disaggregated price developments and at wage-price formation in depth is particularly valuable. It sheds light on how waves of broad-based inflation can arise and propagate from sector-specific relative price shocks and on the relative roles of cyclical and structural forces in determining the likelihood and intensity of wage-price spirals.

The analysis highlights major differences between low- and high-inflation regimes and hence the criticality of transitions.

A low-inflation regime has significant self-stabilising properties. What is measured as inflation is, in large part, the reflection of relative or sector-specific price changes that tend to have a transitory impact on the inflation level. In such an environment, inflation has little effect on the wage and price formation as it loses significance as a factor influencing behaviour. Central bank credibility is instrumental in hardwiring the regime and increasing its robustness.

High-inflation regimes do not have such self-stabilising properties. Inflation becomes a focal point for agents' behaviour and wage-price formation becomes more sensitive to relative price shocks. Higher inflation, in turn, induces changes in more structural features of wage formation, such as indexation and centralised wage bargaining, which help entrench the regime. It also undermines central bank credibility, further unmooring the inflation process. The experience with the oil price shocks of the 1970s illustrates the mechanisms at work.

Because of the sensitivity of agents' behaviour to the level of inflation, transitions are self-reinforcing and hence challenging. They are challenging for the models typically used to explain and forecast inflation, which are ill-suited to capturing such behavioural changes. And they are especially challenging for policymakers, because of endemic uncertainty and the possibility of tipping points.

The under the hood perspective sheds light on how monetary policy can best secure a low-inflation regime. The perspective underscores the importance of navigating the transitions and the associated difficulties. Transitioning back from a high-inflation regime can be very costly once it becomes entrenched. All this puts a premium on a timely and firm response. Central banks fully understand that the long-term benefits far outweigh any short-term costs. And that credibility is too precious an asset to be put at risk.

Endnotes

1 See Carstens (2022).

2 The word "inflation" emerged in the mid-19th century (see eg Bryan (1997)). At that time, it was used to denote changes in the volume of notes and deposits in circulation. Given the metallic standards of those days, the loss of purchasing power, and hence changes in the overall price level, were termed "depreciation". It was only considerably later that the term took on the current connotations of an increase in the general price of goods and services. In his *Tract*, Keynes (1924) defined inflation as "an expansion in the supply of money to spend relatively to the supply of things to purchase", while in *How to pay for the war?* he consistently refers to "price inflation" (Keynes (1940)).

3 For a detailed discussion, see Reis and Watson (2010).

4 See eg Eichenbaum et al (2011).

5 Hyperinflation is sometimes defined as an inflation rate exceeding 50% per month.

6 See Kiguel (1989).

7 See Benati (2008) and Kim and Lin (2012) for cross-country evidence.

8 Beginning with Taylor (2000), it has been recognised that a low-inflation environment contributes to reduced exchange rate pass-through.

9 See eg Altissimo et al (2009).

10 For a thought-provoking review of how inflation expectations have become so prominent in modern macroeconomics, see Rudd (2021).

11 See Gilchrist and Zakrajšek (2019).

12 See Forbes (2019).

13 See Filardo et al (2020).

14 See Auer et al (2017).

15 See also Box IV.A in BIS (2017), Lombardi et al (2020) and Ratner and Sim (2022).

16 See Sims (2010).

17 See Volcker (1983). The formulation of price stability used by Greenspan (1996) was similar: "That state in which expected changes in the general price level do not effectively alter business or household decisions".

18 Plentiful evidence for this exists, especially from the 1970s and 1980s for the United States, where contracts often included automatic cost-of-living adjustments, and sometimes even promised large future wage increases, regardless of inflation outcomes. For example, a 40-month contract negotiated in May 1981 for US mine workers guaranteed average 11% annual wage increases over the life of the contract: see Taylor (1983).

[19] High inflation also polarises the political debate, as the allocation of its costs becomes a relevant distributional issue (see also Chapter II in BIS (2021)). In that context, public policies (eg with respect to the minimum wage, or public sector wages) can often play an important role in amplifying, or short-circuiting, wage-price spirals. For example, wage moderation (achieved through consensus) was instrumental in several disinflation episodes throughout the 1980s – see Pereira da Silva and Mojon (2019).

[20] This is most evident during hyperinflations. Paradoxically, extremely short contract lengths when inflation gets completely out of control allow hyperinflations to be brought to an abrupt end, since they contribute to lowering inflation persistence.

[21] See eg Rich and Tracy (2004), Fregert and Jonung (2008) and Christofides and Peng (2006) for US, Swedish and Canadian evidence, respectively.

[22] Note that indexation still plays an important role in the adjustment of pensions. While pensions do not directly contribute to inflation, since they do not reflect the cost of production, they contribute to demand and hence the inertia of price changes.

[23] See eg Eichengreen and Hausmann (2010) and Carstens and Shin (2019).

[24] Note that this is especially the case for large AEs. In smaller and more open EMEs, a stronger transmission of monetary policy through exchange rate fluctuations, and hence its direct effect on the prices of imported goods, will arguably lead to a broader inflationary response.

[25] See Ahmed et al (2021).

[26] There are many possible reasons for this loss of traction. Low nominal interest rates can harm bank profitability and hence banks' lending capacity. When interest rates fall towards zero, market participants would see less potential for further cuts. Persistently low rates may create disincentives to address debt overhangs, undermining efficient resource allocation and productivity as well as creating so-called zombie firms. Last but not least, the effects of real interest rates on consumption and investment could become weaker: low rates might encourage people to save more for their retirement to make up for lower expected returns and, at the margin, firms may not invest more once rates fall below hurdle rates.

[27] See Pereira da Silva and Mojon (2019) and the references therein.

[28] See Reis (2020).

[29] See Carstens (2022).

[30] This is a "hall of mirrors" effect as suggested by Morris and Shin (2002). Markets come to trust the central bank too much and the central bank, in turn, relies too much on market signals.

Technical annex

Graph 1.A: Annual data for AT, AU, BE, CA, CH, DE, DK, ES, FI, FR, GB, IT, JP, NL, NO, NZ, PT, SE and US.

Graph 1.B: Belligerents = DE, FR, GB, IT, JP and US; Non-belligerents = CH, ES, PT and SE.

Graph 2: For each country, the variance of aggregate 12-month inflation, measured by the weighted average of 12-month log-difference of underlying sectoral prices, is decomposed into the portion attributable to the variance of 12-month log-difference of sectoral prices and the portion attributable to the covariance of 12-month log-differences of sectoral prices between sectors. The weights are given by a geometric average of sectoral expenditure shares in month *t*–12 and month *t*. The red line shows the proportion of total 12-month price-change variance in each five-year rolling window due to the common inflation component. The common inflation component is defined as the first principal component of 12-month log changes of sectoral price indices underlying the US PCE deflator.

Graph 3.B: Estimated on panel data with country fixed effects using local projections. Oil supply shocks as identified in Baumeister and Hamilton (2019), downloaded on 14 March 2022. The sample covers AT, AU, BE, BR, CA, CH, CL, CN, CO, CZ, DE, DK, ES, FI, FR, GB, HK, HU, ID, IE, IL, IN, IT, JP, KR, MX, MY, NL, NO, NZ, PL, PT, RU, SE, SG, TH, TR, US and ZA during the period Feb 1975–Feb 2021. High (low) inflation regime corresponds to five-year inflation moving average above (below) 5%.

Graph 3.C: Based on an exchange-rate pass-through equation estimated on panel data, in which the (annualised) log-difference of each country's CPI between months *t*–1 and month *t*+2 is regressed on the log-difference of the country's bilateral USD exchange rate between month *t*–1 and month *t* and the interaction of the exchange rate log return with trend CPI inflation in month *t*–1, where trend inflation is measured by the trailing 60-month average of the 12-month log-difference of the CPI. The panel specification also includes lags from 1 to 11 of the (annualised) monthly log-difference of the CPI, as well as country and time fixed effects. The sample covers AT, BE, BR, CA, CH, CL, CN, CO, CZ, DE, DK, ES, FI, FR, GB, HK, HU, ID, IE, IL, IN, IT, JP, KR, MX, MY, NL, NO, PE, PL, PT, RO, RU, SE, SG, TH, TR and ZA over Mar 1973–Dec 2019.

Graph 4.A: Based on quarterly CPI data, for CA, JP, KR and MX; monthly PCE deflator data for US. High-inflation regime samples: CA, Q4 1971–Q4 1990; JP, Q4 1970–Q4 1979; KR, Q4 1985–Q4 1997; MX, Q1 1983–Q4 2002; US, Jan 1965–Dec 1985. Low-inflation regime samples: CA, Q1 1991–Q4 2019; JP, Q1 1980–Q4 2019; KR, Q1 1998–Q4 2019; MX, Q1 2003–Q4 2019; US, Jan 1986–Dec 2019.

Graph 4.B: Measure of persistence based on Días and Marques (2010). High-inflation regime samples: CA, Dec 1971–Dec 1990; JP, Dec 1970–Dec 1979; KR, Dec 1985–Dec 1997; MX, Jan 1983–Dec 2002; US, Jan 1965–Dec 1985. Low-inflation regime samples: CA, Jan 1991–Dec 2019; JP, Jan 1980–Dec 2019; KR, Jan 1998–Dec 2019; MX, Jan 2003–Dec 2019; US, Jan 1986–Dec 2019.

Graph 5.A-B: The sample covers AL, AR, AT, AU, BA, BE, BG, BR, CA, CH, CL, CN, CO, CR, CS, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, ID, IE, IL, IN, IS, IT, JP, KR, LT, LU, LV, ME, MK, MT, MX, NL, NO, NZ, PL, PT, RO, RS, SE, SI, SK, TR, US and XK (subject to data availability).

Graph 5.A: Details on the construction of the index can be found in the OECD/AIAS ICTWSS database codebook, available at www.oecd.org/employment/ictwss-database.htm.

Graph 5.C: Based on a wage equation, estimated on panel data, in which nominal wage growth is regressed on past inflation, the unemployment gap and productivity growth, as well as on their interaction with a measure of workers' bargaining power. This measure is constructed as the first principal component of three OECD indicators of labour market institutions: union coverage, union density and employment protection legislation (Lombardi et al (2020)). The panel covers AU, BE, CA, DE, DK, ES, FR, GB, IE, IT, JP, NL, SE and US.

Graph 6.A-B: Similarity index based on Mink et al (2007), modified by adding 1 so that it lies in the range between 0 and 1, with higher numbers indicating great similarity of price changes at each point in time. The reference 12-month log price change is the unweighted cross-sectional median. 12-month headline inflation is shown on a logarithmic scale.

Graph 6.A: The sample covers AT, BE, CA, CH, DE, DK, ES, FI, FR, GB, IE, IT, JP, NL, NO, PT, SE and US over Jan 1959–Apr 2022 (subject to data availability).

Graph 6.B: The sample covers BR, CL, CO, CZ, HU, KR, MX, PE, PL, RO, SG and TR over Jan 1969–Apr 2022 (subject to data availability).

Graph 6.C: The sample covers AL, AR, AU, AT, BE, BG, BA, BR, CA, CH, CL, CR, CS, CY, CZ, DE, DK, ES, EE, FI, FR, GB, GR, HR, HU, IE, IS, IL, IT, JP, KR, LT, LU, LV, MX, MK, MT, ME, NL, NO, NZ, PL, PT, RO, RS, SK, SI, SE, TR, US and XK (subject to data availability).

Graph 7.A: A high-inflation regime is defined as the periods in which the eight-quarter moving median of past core inflation is above 5%. Quarterly estimates are based on a wage equation, in which inflation at time t+4 is regressed on nominal wage growth, its interaction with the high-inflation regime dummy, the unemployment gap and productivity growth at time t, as well as on country and time fixed effects. The panel includes AU, BE, CA, DE, DK, ES, FR, GB, IE, IT, JP, NL, SE and US.

Graph 7.B-C: Based on a VAR model of the US economy with three lags, featuring (in this order) PCE and PPI inflation, industrial production growth, employment growth, wage growth, the two-year Treasury yield, the Moody's Baa-Aaa corporate bond credit spread and growth in WTI oil prices. Shocks to nominal wage growth are obtained using a Cholesky decomposition based on the ordering above.

Graph 8: Based on quarterly data for AU, BE, CA, DE, DK, ES, FR, GB, IE, IT, JP, NL, SE and US.

Graph 8.A: Quarterly estimates are based on a wage equation, in which nominal wage growth at time t+4 is regressed on inflation, its interaction with the high-inflation regime dummy, the unemployment gap and productivity growth at time t, as well as country and time fixed effects.

Graph 9: Based on a panel cointegrating model of nominal wages and consumer prices for a set of advanced economies. The model is non-linear in that it separates the effect of positive and negative deviations from the cointegrating relationship. In addition to the error correction term, and price and wage inflation, the short-run equations also include the unemployment gap, labour productivity growth as well as on country and time fixed effects. The panel includes AU, BE, CA, DE, DK, ES, FR, GB, IE, IT, JP, NL, SE and US over Q1 1968–Q4 2021 (subject to data availability).

Graph 10.A: Based on unbalanced panel regressions with country fixed effects. The control variables include inflation, the change in the exchange rate (in logs), real GDP growth, the change in the oil price denominated in local currency (in logs), US policy interest rate and US equity return volatility. The sample covers BR, CL, CN, CO, HK, HU, ID, IL, IN, KR, MX, PE, PH, PL, RO, RU, TH, TR and ZA over 1991–2019, using annual data.

Graph 10.B: Based on unbalanced panel quantile regressions with country fixed effects. To compute the distributions, all other variables are set to their means. The control variables include real GDP growth, inflation, the change in the exchange rate (in logs) and the change in the oil price denominated in local currency (in logs). See Banerjee et al (2020) for details on the methodology. AEs: AT, AU, BE, CA, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, JP, NL, NO, NZ, PT, SE and US. EMDEs: BO, BR, CL, CN, CO, DO, GH, HK, HN, HT, HU, ID, IL, IN, KR, MX, NI, PE, PH, PL, RO, RU, TH, TR, UY and ZA. The sample covers 1960–2019, using annual data.

Graph 10.C: Based on unbalanced panel quantile regressions with country fixed effects. The control variables include real GDP growth, current inflation, the change in the exchange rate (in logs) and the change in the oil price denominated in local currency (in logs). See Banerjee et al (2020) for details on the methodology. EMDEs includes BO, BR, CL, CN, CO, DO, GH, HK, HN, HT, HU, ID, IL, IN, KR, MX, NI, PE, PH, PL, RO, RU, TH, TR, UY and ZA. The low/high debt classification is defined based on the sample median. The sample covers 1960–2019, using annual data.

Graph 11.A: For BR, CA, DE, EA, GB, IN, JP, NZ and US, median value. For KR, PH, SE and ZA, mean value. Sample start dates: BR, Q1 2015; CA, Q4 2014; DE, Q2 2019; EA, Q1 2004; GB and SE, Q2 2015; IN, Q3 2009; JP, Q2 2006; KR, Q1 2013; NZ, Q2 2007; PH, Q1 2017; US, Q4 1989. Sample end date: Q1 2021.

Graph 11.B: The sample covers Q1 2010–Q4 2018.

Graph 12: The common inflation component is defined as the first principal component of monthly log changes of 131 sectoral price indices underlying the US PCE deflator. The idiosyncratic component of sectoral log price changes corresponds to the residuals from the regression of monthly sector-specific log price changes on the common inflation component. The high-frequency monetary policy surprises are constructed using the methodology developed by Miranda-Agrippino and Ricco (2021). Impulse responses are estimated using local projections; see Borio et al (2021) for details. The sample covers Jul 1992–Dec 2018 (subject to data availability).

Graph 13.B: Similarity index based on Mink et al (2007); see the note to Graph 6.A-B.

Graph A3: Based on a VAR model with three lags, estimated over the sample May 2004–Dec 2019.

Graph C1.A: 2021 for GDP per capita and 2022 (or latest) for the weight of food and energy. The sample covers AT, AU, BE, BG, BR, CH, CL, CO, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IN, IS, IT, JP, KR, LT, LU, LV, MK, MT, MX, NL, NO, NZ, PE, PH, PL, PT, RO, RS, SE, SG, SI, SK, TR and US.

Graph C1.B: High–inflation regime dates: DE, FR, IT, Jan 1970–Dec 1999; GB, Jan 1970–Dec 1992; JP, Jan 1970–Dec 1979 and US, Jan 1970–Dec 1985. For FR and GB, core inflation starts in Jan 1971. Low-inflation regime dates for DE, Jan 2000–May 2022 (Apr 2022 for core and trimmed inflation); FR, Jan 2000–Apr 2022; GB, Jan 1993–Apr 2022; IT, Jan 2000–Apr 2022; JP, Jan 1980–Apr 2022; US, Jan 1986–Apr 2022. For JP, trimmed inflation starts in Jan 2001. For US, the trimmed mean CPI excludes 8% of the CPI components with the highest and lowest one-month price changes from each tail of the price-change distribution resulting in a 16% trimmed-mean inflation estimate (calculated by the Federal Reserve Bank of Cleveland). For JP, 20% trimmed-mean inflation estimate (calculated by the Bank of Japan); for FR, DE, IT and GB, 16% trimmed-mean inflation estimate (own calculations).

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III. The future monetary system

Key takeaways

- A burst of creative innovation is under way in money and payments, opening up vistas of a future digital monetary system that adapts continuously to serve the public interest.
- Structural flaws make the crypto universe unsuitable as the basis for a monetary system: it lacks a stable nominal anchor, while limits to its scalability result in fragmentation. Contrary to the decentralisation narrative, crypto often relies on unregulated intermediaries that pose financial risks.
- A system grounded in central bank money offers a sounder basis for innovation, ensuring that services are stable and interoperable, domestically and across borders. Such a system can sustain a virtuous circle of trust and adaptability through network effects.
- New capabilities such as programmability, composability and tokenisation are not the preserve of crypto, but can instead be built on top of central bank digital currencies (CBDCs), fast payment systems and associated data architectures.

Introduction

Every day, people around the world make more than 2 billion digital payments.[1] They pay for goods and services, borrow and save and engage in a multitude of financial transactions. Every time they do so, they rely on the monetary system – the set of institutions and arrangements that surround and support monetary exchange.

At the heart of the monetary system stands the central bank. As the central bank issues money and maintains its core functions, trust in the monetary system is ultimately grounded in trust in the central bank. However, the central bank does not operate in isolation. Commercial banks and other private payment service providers (PSPs) execute the vast majority of payments and offer customer-facing services. This division of roles promotes competition and gives full play to the ingenuity and creativity of the private sector in serving customers. Indeed, private sector innovation benefits society precisely because it is built on the strong foundations of the central bank.

The monetary system with the central bank at its centre has served society well. Yet digital innovation is expanding the frontier of technological possibilities, placing new demands on the system.

Far-reaching innovations, such as those in the crypto universe, entail a radical departure. The crypto universe builds on the premise of decentralisation. Rather than relying on central bank money and trusted intermediaries, crypto envisages checks and balances provided by a multitude of anonymous validators so as to keep the system self-sustaining and free from the influence of powerful entities or groups. Decentralised finance, or "DeFi", seeks to replicate conventional financial services within the crypto universe. These services are enabled by innovations such as programmability and composability (see glossary) on permissionless blockchains. Such systems are "always on", allowing for global transactions 24/7, based on open-source code and knowing no borders.

However, recent events have revealed a vast gulf between the crypto vision and its reality. The implosion of the TerraUSD stablecoin and the collapse of its twin coin Luna have underscored the weakness of a system that is sustained by selling coins for speculation. In addition, it is now becoming clear that crypto and DeFi have deeper structural limitations that prevent them from achieving the levels of efficiency, stability or integrity required for an adequate monetary system. In particular, the crypto universe lacks a nominal anchor, which it tries to import, imperfectly, through stablecoins. It is also prone to fragmentation, and its applications cannot scale without compromising security, as shown by their congestion and exorbitant fees. Activity in this parallel system is, instead, sustained by the influx of speculative coin holders. Finally, there are serious concerns about the role of unregulated intermediaries in the system. As they are deep-seated, these structural shortcomings are unlikely to be amenable to technical fixes alone. This is because they reflect the inherent limitations of a decentralised system built on permissionless blockchains.

This chapter sets out an alternative vision for the future, one that builds on central bank public goods. This will ensure that innovative private sector services are securely rooted in the trust provided by central bank money.

Scaling on the back of network effects, central bank digital currencies (CBDCs) and retail fast payment systems (FPS) are well placed to serve the public interest through greater convenience and lower costs, while maintaining the system's integrity. Decentralisation and permissioned distributed ledger technology (DLT) can also play a constructive role, eg when central banks work together in multi-CBDC arrangements. These innovative payment rails are fully compatible with programmability, composability and tokenisation to support faster, safer and cheaper payments and settlement, both within and across borders. In this way, the future monetary system will be adaptable, allowing private sector innovation to flourish while avoiding the drawbacks of crypto. Such initiatives could open up a new chapter in the global monetary system.

This chapter is organised as follows. To set the stage, it first describes today's monetary system and the high-level objectives it needs to achieve, and to what extent changes in technology and the economic environment have opened up room for improvement. The next section discusses the promise and pitfalls of crypto and DeFi innovations. The chapter then discusses a vision for the future monetary system, built on central bank public goods. The final section concludes.

What do we want from a monetary system?

The monetary system is the set of institutions and arrangements that supports monetary exchange. It consists of money and payment systems.[2] What is required from such a system to serve society? While there is no canonical list of necessary features, a number of high-level goals stand out (Table 1, first column).

To ensure the **safety and stability** of the system, money needs to fulfil three functions: as a store of value, a unit of account and a medium of exchange. Where the monetary system relies on key nodes or entities (whether public or private), they need to be **accountable**, through specific mandates for public authorities and through proper regulation and supervision for private entities. The monetary system should be **efficient**, enabling reliable, fast payments to support economic transactions both at scale and also at low cost. Access to basic payments services at affordable prices, in particular transaction accounts, should be universal to spread the benefits of economic activity, promoting **financial inclusion**. Not least, the system must protect privacy as a fundamental right, and provide **user control** over

High-level goals of the monetary system — Table 1

High-level goals	Today's monetary system	Crypto universe (to date)	Future monetary system (vision)
1. **Safety and stability** – money needs to perform fundamental functions: as a store of value, unit of account and medium of exchange	Sovereign currencies can offer price stability, and public oversight has helped achieve safe and robust payment systems	Cryptocurrencies do not perform money's fundamental functions, and stablecoins need to import their credibility	Innovations grounded in trust in the central bank feature stable sovereign currencies and safe payment systems
2. **Accountability** – public mandates and regulation should ensure that key nodes in the system are accountable and transparent to users and society	Supervision, regulation and oversight tackle risks, promote competition and protect consumers, but public mandates may need to adapt to change	Crypto and DeFi create a parallel financial system to circumvent regulation, with no accountability to the general public	Clear mandates and regulation balance risks and benefits so as to harness innovation and stimulate efficiency
3. **Efficiency** – the system should provide low-cost, fast payments and throughput	Domestic payments are often expensive and financial institutions collect rents	High congestion and rents lead to costly transactions and new speculative incentives	New payment systems can significantly reduce payment costs and rents, supporting economic activity
4. **Inclusion** – the system should ensure universal access to basic services at affordable prices	Many people lack access to transaction accounts and digital payment instruments	Crypto and DeFi have not yet served to enhance financial inclusion	New service providers and interfaces can address barriers to inclusion and better serve the unbanked
5. **User control over data** – data governance arrangements should ensure users' privacy and control over data	Users trust intermediaries to keep data safe, but they do not have sufficient control over their data	Transactions are public on the blockchain – which will not work with "real names"	New data architectures can give users privacy and control over their data
6. **Integrity** – the system should avoid illicit activity such as money laundering, financing of terrorism and fraud	Payment systems are subject to extensive regulation, but illicit activity persists in cash and account fraud	Pseudo-anonymity is prone to abuse by illicit actors, and the DeFi sector is rife with fraud and theft; identification is needed	New technologies can help to better prevent illicit activity and improve on today's systems
7. **Adaptability** – the system should anticipate future developments and users' needs and foster competition and innovation	Payment systems are adapting to demands, but are not yet at the technological frontier	Programmability, composability and tokenisation give scope for new functions	Programmability, composability and tokenisation can be offered in a CBDC or through tokenised deposits
8. **Openness** – the system should allow for seamless cross-border use	Despite progress, cross-border payments are still slow, opaque and expensive	DeFi is by nature borderless and allows global transactions, but without adequate oversight	Multi-CBDC arrangements and other reforms mean cheaper, faster and safer cross-border transactions

Green denotes that a policy goal is broadly fulfilled, yellow that there is room for improvement and red that it is not generally fulfilled.

Source: BIS.

financial data. The **integrity** of the system must be protected, by guarding against illicit activity such as money laundering, financing of terrorism and fraud.

The monetary system is not just a snapshot of the economy as it exists today; it needs to evolve with structural changes in the economy and society. For this reason, the means of reaching the high-level goals set out in Table 1 should evolve with the monetary system itself and the technology underpinning it. In short, the monetary system must be **adaptable**: it should *anticipate* future developments and user needs. It must be attuned to technological developments and respond to the changing demands of households and businesses, and it must foster competition and innovation. To better serve an increasingly interconnected world, the monetary system also needs to be **open**, interoperable and flexible, both domestically and across borders. Just as economic transactions transcend borders, the monetary system will need to serve a seamless web of interconnected entities, rather than sparsely connected islands of activity.

Today's monetary system has come some way towards these high-level goals, but there is still some way to go. Changes in users' needs and the concomitant shifts in technology have pointed to areas for improvement (Table 1, second column). Current payment services can sometimes be cumbersome and costly to use, in part reflecting a lack of competition. Cross-border payments are particularly expensive, opaque and slow: they usually involve one or more correspondent banks to settle a transaction, using ledgers built on different technologies.[3] In addition, a large share of adults, especially in emerging market and developing economies, still have no access to digital payment options. But a globalised world that features an ever-growing digital economy requires a monetary system that allows everyone to make financial transactions domestically and globally in a safe, sound and efficient way. Catering to these changes in the demands that society places in the monetary system calls for advances in technology and institutional arrangements.

The promise and pitfalls of crypto

The crypto universe is in turmoil. The implosion of the TerraUSD stablecoin and its twin coin Luna is only the most spectacular failure in the sector, with many lesser-known coins having seen a collapse in price of more than 90% relative to their peak in 2021. Crypto commentators have begun to refer to recent events as the start of a "crypto winter".

As dramatic as these recent price collapses have been, focusing on the price action alone diverts attention away from the deeper structural flaws in crypto that render them unsuitable as the basis for a monetary system that serves society (Table 1, third column).

The prevalence of stablecoins, which attempt to peg their value to the US dollar or other conventional currencies, indicates the pervasive need in the crypto sector to piggyback on the credibility provided by the unit of account issued by the central bank. In this sense, stablecoins are the manifestation of crypto's search for a nominal anchor. Stablecoins resemble the way that a currency peg is a nominal anchor for the value of a national currency against that of an international currency – but without the institutional arrangements, instruments, commitments and credibility of the central bank operating the peg. Providing the unit of account for the economy is the primary role of the central bank. The fact that stablecoins must import the credibility of central bank money is highly revealing of crypto's structural shortcomings. That stablecoins are often less stable than their issuers claim shows that they are at best an imperfect substitute for sound sovereign currency.

Stablecoins also play a key role in facilitating transactions *across* the plethora of cryptocurrencies that have mushroomed in recent years. At the latest count there were over 10,000 coins on many different blockchains that competed for the attention of speculative buyers.

The proliferation of coins reveals another important structural flaw with crypto – namely the *fragmentation* of the crypto universe, with many incompatible settlement layers jostling for a place in the spotlight.

This fragmentation of the crypto universe raises serious questions as to the suitability of crypto as money. Money is a coordination device that serves society through its strong network effects. The more users flock to a particular form of money, the more users it attracts. For this reason, money has the "winner takes all" property, in which network effects lead to the dominance of one version of money as the transactions medium that is generally accepted throughout the economy. The fragmentation of the crypto universe points in a very different direction: as explained below, the more users flock to one blockchain system, the worse is the congestion and the higher are the transaction fees, opening the door to the entry of newer rivals who may cut corners on security in favour of higher capacity. So, rather than the familiar monetary narrative of "the more the merrier", crypto displays the property of "the more the sorrier". It is this tendency toward fragmentation that is perhaps crypto's greatest flaw as the basis for a monetary system.

Nevertheless, crypto offers a glimpse of potentially useful features that could enhance the capabilities of the current monetary system. These stem from the capacity to combine transactions and to execute the automatic settlement of bundled transactions in a conditional manner, enabling greater functionality and speed. Thus, one question to consider is how the useful functionalities of crypto can be incorporated in a future monetary system that builds on central bank money.

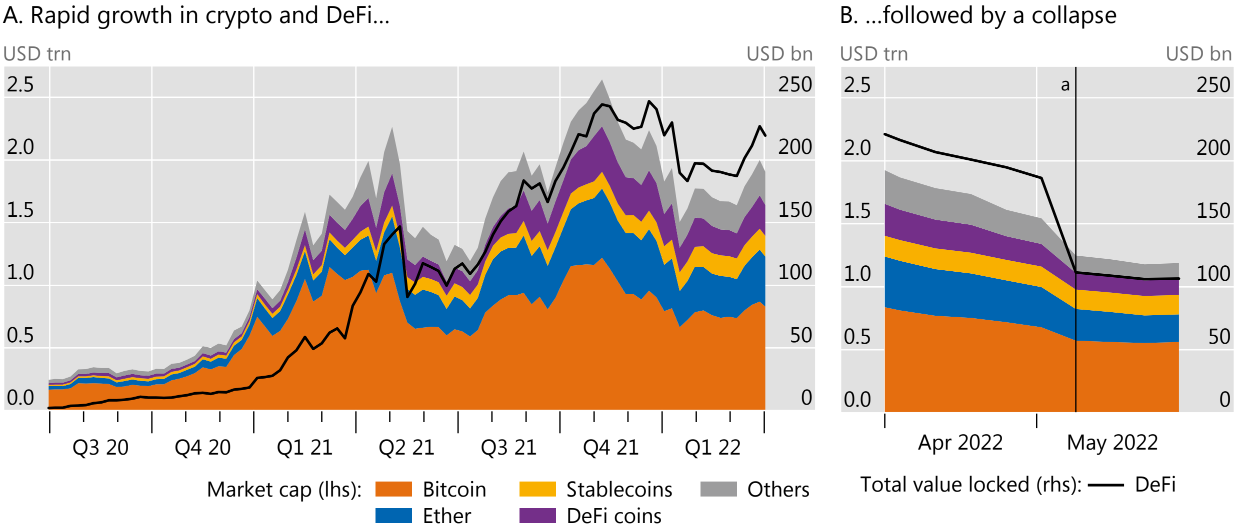
In order to develop the deeper insights on the flaws and possibilities of crypto, it is instructive first to explain some basic building blocks of the crypto world.

The building blocks of crypto

Crypto purports to reduce the heft of intermediaries and has been described as a broader movement toward decentralised finance and even a more decentralised internet ("Web 3.0" or "Web3"). The touted benefit is to democratise finance, granting users greater control over their data. Prior to the recent crash, the market size of cryptocurrencies and DeFi had expanded rapidly (Graph 1).

Crypto has its origin in Bitcoin, which introduced a radical idea: a decentralised means of transferring value on a permissionless blockchain. Any participant can act as a validating node (see glossary) and take part in the validation of transactions on a public ledger (ie the permissionless blockchain). Rather than relying on trusted

Market size of cryptocurrencies and DeFi[1] — Graph 1



[a] TerraUSD and Luna collapse starting on 9 May 2022.

[1] See technical annex for details.

Sources: CoinGecko; Defi Llama; BIS.

intermediaries (such as banks), record-keeping on the blockchain is performed by a multitude of anonymous, self-interested validators.

Transactions with cryptocurrencies are verified by decentralised validators and recorded on the public ledger. If a seller wants to transfer cryptocurrencies to a buyer, the buyer (whose identity is hidden behind their cryptographic digital signature) broadcasts the transaction details, eg transacting parties, amount or fees. Validators (in some networks called "miners") compete to verify the transaction, and whoever is selected to verify then appends the transaction to the blockchain. The updated blockchain is then shared among all miners and users. The history of all transactions is hence publicly observable and tied to specific wallets, while the true identities of the parties behind transactions (ie the owners of the wallets) remain undisclosed. By broadcasting all information publicly, the system verifies that the transaction is consistent with the history of transfers on the blockchain, ie that the cryptocurrency actually belongs to the seller and has not been double-spent.

However, for a decentralised governance system, economic incentives are key. The limits of the system are set by the laws of economics rather than the laws of physics. In other words, not only the technology but also the incentives need to work. Miners (or validators) are compensated with monetary rewards for performing their tasks according to the rules so that the system becomes self-sustaining. Rewards, paid in crypto, can come in the form of transaction fees but can also stem from rents that accrue to "staking" one's coins in a proof-of-stake blockchain. The larger the stake, the more often a node will serve as validator, and the larger the rents.

Since the advent of Bitcoin in 2009, many other blockchains and associated crypto coins have entered the scene, most notably Ethereum, which provides for the use of "smart contracts" and "programmability" (see glossary). Smart contracts, or self-executing code that triggers an action if some pre-specified conditions are met, can automate market functions and obviate the intermediaries that were traditionally required to make decisions. As the underlying code is publicly available, it can be scrutinised, making smart contracts transparent and reducing the risk of manipulation. An important feature of smart contracts is their composability, or the capacity to combine different components in a system. Users can perform complex transactions on the same blockchain by combining multiple instructions within one single smart contract – "money legos". They can create a digital representation of assets through "tokenisation" (see glossary). As smart contracts cannot directly access information that resides "off-chain", ie outside the specific blockchain, they require mediators to provide such data (so-called oracles).[4]

Newer blockchains, with Terra (before its collapse) being a prominent example, have been touted as "Ethereum killers" in that they boast higher capacity and larger throughput (see glossary). However, these changes bring new problems. Capacity is often increased through greater centralisation in the validation mechanisms, weakening security and concentrating the benefits for insiders, as explained below.[5]

Stablecoins in search of a nominal anchor

A key development in the crypto universe is the rise of decentralised finance, or "DeFi". DeFi offers financial service and products, but with the declared objective of refashioning the financial system by cutting out the middlemen and thereby lowering costs.[6] To this end, DeFi applications publicly record pseudo-anonymous transactions in cryptocurrencies on permissionless blockchains. "Decentralised applications" (dApps) featuring smart contracts allow transactions to be automated. To reach consensus, validators are incentivised through rewards.

While the DeFi ecosystem is evolving rapidly, the main types of financial activity continue to be those already available in traditional finance, such as lending, trading and insurance.[7] Lending platforms let users lend out their stablecoins with interest to borrowers that post other cryptocurrencies as collateral. Decentralised exchanges (DEXs) represent marketplaces where transactions occur directly between cryptocurrency or stablecoin traders, with prices determined via algorithms. On DeFi insurance platforms, users can insure themselves against eg the mishandling of private keys, exchange hacks or smart contract failures. As activities almost exclusively involve exchanging one stablecoin or cryptocurrency for another, and do not finance productive investments in the real economy, the system is mostly self-referential.

Stablecoins play a key role in the DeFi ecosystem. These are so-called because they are usually pegged to a numeraire, such as the US dollar, but can also target the price of other currencies or assets (eg gold). In this sense, they often import the credibility provided by the unit of account issued by the central bank. Their main use case is to overcome the high price volatility and low liquidity of unbacked cryptocurrencies, like Bitcoin. Their use also avoids frequent conversion between cryptocurrencies and bank deposits in sovereign currency, which is usually associated with significant fees. Because stablecoins are used to support a wide range of DeFi activities, turnover in stablecoins generally dwarfs that of other cryptocurrencies.

The two main types of stablecoin are asset-backed and algorithmic. Asset-backed stablecoins, such as Tether, USD Coin and Binance USD, are typically managed by a centralised intermediary who invests the underlying collateral and coordinates the coins' redemption and creation. Assets can be held in government bonds, short-term corporate debt or bank deposits, or in other cryptocurrencies. In contrast, algorithmic stablecoins, such as TerraUSD before its implosion, rely on complex algorithms that automatically rebalance supply to maintain their value relative to the target currency or asset. To avoid reliance on fiat currency, they often do so by providing users with an arbitrage opportunity relative to another cryptocurrency.

Despite their name, stablecoins – in particular, algorithmic ones – are less stable than their issuers claim. In May 2022, TerraUSD entered a death spiral, as its value dropped from $1 to just a few cents over the course of a few days (see Box A). In the aftermath, other algorithmic stablecoins came under pressure. But so did some asset-backed stablecoins, which have seen large-scale redemptions, temporarily losing their peg in the wake of the shock. Redemptions were more pronounced among stablecoins whose issuers did not disclose the composition of reserve assets in detail, presumably reflecting investors' worries that such issuers might not be able to guarantee conversion at par.

Indeed, commentators have warned for some time that there is an inherent conflict of interest in stablecoins, with an incentive for issuers to invest in riskier assets. Economic history is littered with attempts at private money that failed, leading to losses for investors and the real economy. The robustness of stablecoin stabilisation mechanisms depends crucially on the quality and transparency of their reserve assets, which are often woefully lacking.[8]

Yet even if stablecoins were to remain stable to some extent, they lack the qualities necessary to underpin the future monetary system. They must import their credibility from sovereign fiat currencies, but they benefit neither from the regulatory requirements and protections of bank deposits and e-money, nor from the central bank as a lender of last resort. In addition, they tie up liquidity and can fragment the monetary system, thus undermining the singleness of the currency.[9] As stablecoins are barely used to pay for real-world goods and services, but underpin the largely self-referential DeFi ecosystem, some have questioned whether stablecoins should be banned.[10] As will be discussed below, there is more promise in sounder representations of central bank money and liabilities of regulated issuers.

Box A

The collapse of the TerraUSD stablecoin

The implosion of TerraUSD (UST) highlights inherent fragilities in some versions of stablecoins. The use of UST grew rapidly over 2021–22 so that, prior to its collapse, it was the third largest stablecoin, with a peak market capitalisation of $18.7 billion. An *algorithmic stablecoin*, it maintained value by adjusting supply in an automated arbitrage trading strategy with another cryptocurrency, Luna, on the Terra blockchain. UST aimed to keep a one-for-one peg to the US dollar by being convertible into one dollar's worth of Luna, and vice versa. For example, should Terra fall to 99 cents, a user could purchase UST on an exchange for 99 cents and then exchange their UST for $1 worth of new units of Luna on the Terra platform. A crucial aspect of this arrangement was that users would only be willing to exchange UST into Luna if Luna's market capitalisation exceeded that of UST. As Luna had no intrinsic value, its valuation stemmed primarily from the influx of speculative users into the Terra ecosystem. To attract new users, the associated lending protocol Anchor offered a deposit rate of around 20% on UST. As long as users had confidence in the stable value of UST and sustained market capitalisation of Luna, the system could be sustained. The Terra/Luna pairing was regarded as being especially significant as it promised to offer a "self-levitating" version of money that did not piggyback on real-world collateral assets.

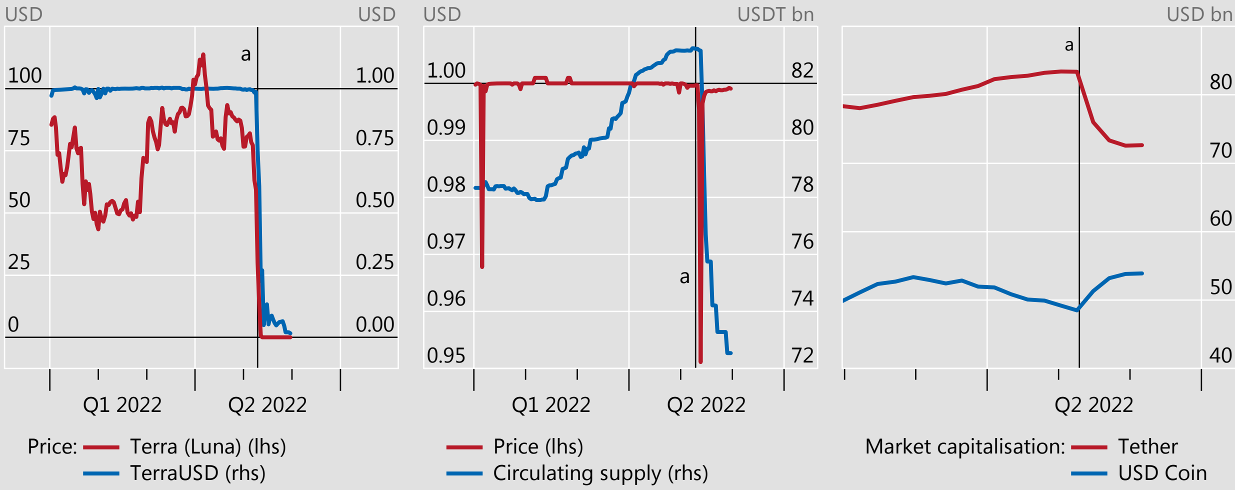
The TerraUSD implosion and fragilities in stablecoins

Graph A1

A. Terra and Luna coins dropped in value rapidly

B. Tether briefly lost its peg and suffered $10bn in outflows[1]

C. Investors moved to USD Coin and other asset-backed stablecoins



[a] TerraUSD and Luna collapse starting on 9 May 2022.

[1] See technical annex for details.

Sources: CoinGecko; CryptoCompare; Messari; BIS.

However, this hope proved unfounded. Once investors lost confidence in the sustainability of the system, the arrangement unravelled. In May 2022, the value of UST plummeted to almost zero (Graph A1.A). As UST dropped below its peg, a classic run dynamic took hold as investors sought to redeem their funds. Users burned their UST on a large scale to mint $1 worth of new Luna, in the hope of selling Luna as long as it still had some value. However, given the size and speed of the shock, confidence evaporated, meaning that there were not enough parties willing to buy all the newly minted Luna coins – and so the price of Luna collapsed.

The UST/Luna implosion spilled over to the largest stablecoin, Tether, which dropped to a value of $0.95 before recovering. It saw outflows of over $10 billion in the subsequent weeks (Graph A1.B). The de-pegging has been linked to Tether's unwillingness to provide details about its reserve portfolio: investors worried about whether Tether had enough high-quality assets that could be liquidated to support the peg. This argument is supported by the inflows experienced by the regulated stablecoin USDC (with better documented reserves), with funds probably coming from Tether (Graph A1.C).

Structural limitations of crypto

In addition to the immediate concerns around stability, crypto suffers from the inherent limitations of permissionless blockchains, which lead inevitably to the system's fragmentation, accompanied by congestion and high fees.[11] Tracing the reasons for fragmentation is revealing, as these highlight that the limitations are not technological but rather stem from the system's incentive structure.

Self-interested validators are responsible for recording transactions on the blockchain. However, in the pseudo-anonymous crypto system, they have no reputation at stake and cannot be held accountable under the law. Instead, they must be incentivised through monetary rewards that are high enough to sustain the system of decentralised consensus. Honest validation must yield higher returns than the potential gains from cheating. Should rewards fall too low, individual validators would have an incentive to cheat and steal funds. The consensus mechanism would fail, jeopardising overall security.

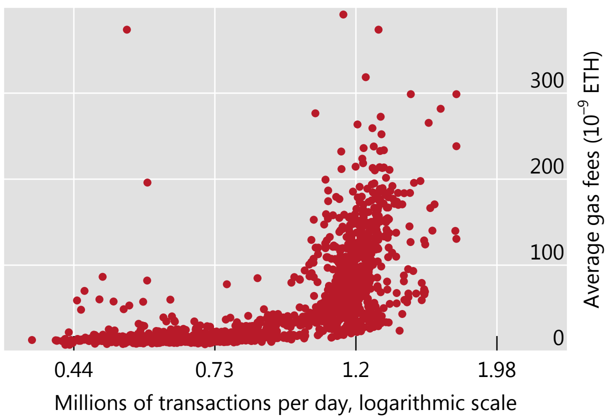
The only way to channel rewards to validators, thus maintaining incentives, is to limit the capacity of the blockchain, thus keeping fees high, sustained by congestion. As validators can choose which transactions are validated and processed, periods of congestion see users offering higher fees to have their transactions processed faster (Graph 2.A).[12]

The limited scale of blockchains is a manifestation of the so-called scalability trilemma. By their nature, permissionless blockchains can achieve only two of three properties, namely scalability, security or decentralisation (Graph 3). Security is enhanced through incentives and decentralisation, but sustaining incentives via fees entails congestion, which limits scalability. Thus, there is a mutual incompatibility between these three key attributes, preventing blockchains from adequately serving the public interest.

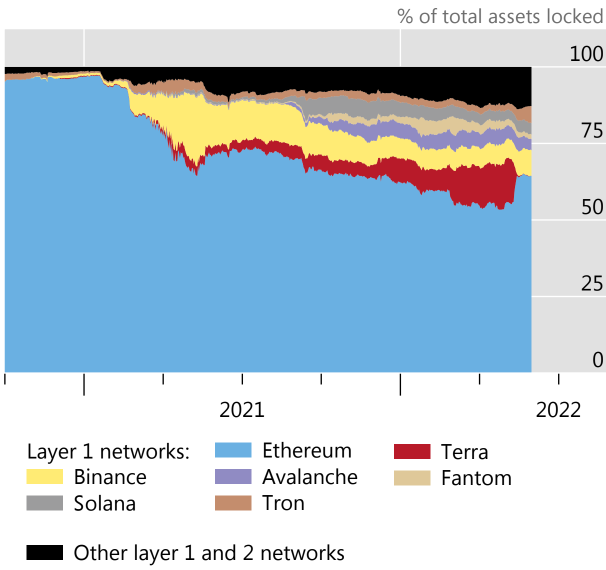
Blockchain congestion leads to fragmentation

Graph 2

A. Network congestion leads to high fees on the Ethereum network[1]



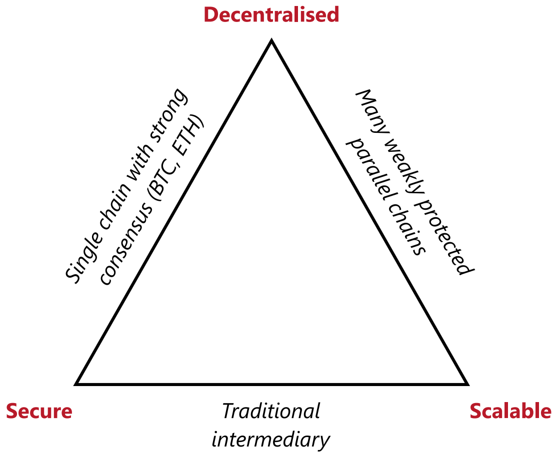
B. Fragmentation of layer 1 blockchains[2]



[1] See technical annex for details. [2] Based on total value locked, which corresponds to the aggregate of all the funds locked in a DeFi smart contract.

Sources: Boissay et al (2022); DeFi Llama; Etherscan; BIS.

Buterin's "scalability trilemma" Graph 3



Sources: Auer et al (2021); Buterin (2021).

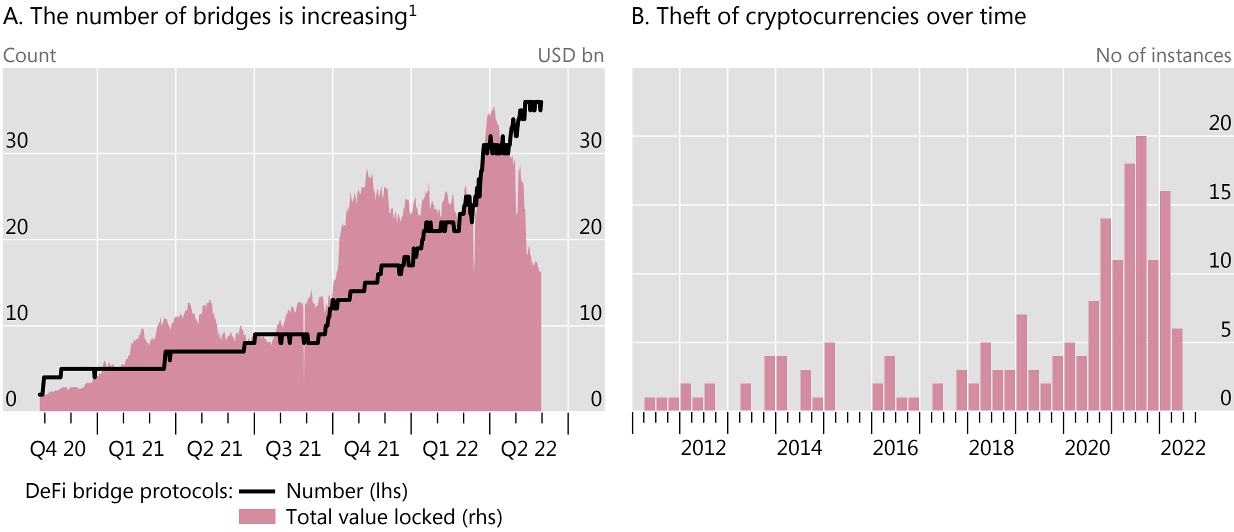
The limited scalability of blockchains has fragmented the crypto universe, as newer blockchains that cut corners on security have entered the fray. The Terra blockchain is just the most prominent of a horde of new entrants (Graph 2.B). Even as recently as the beginning of 2021, Ethereum accounted for almost all of the total assets locked. By early May 2022, this share had already dropped to 50%. The widening wedge (in red) accounted for by the failed Terra blockchain is particularly striking. Terra's collapse highlights the tendency of the crypto universe to fragment through its vulnerability to new entrants that prioritise market share and capacity at the expense of decentralisation and security.

A system of competing blockchains that are not interoperable but sustained by speculation introduces new risks of hacking and theft. Interoperability refers here to the ability of protocols and validators to access and share information, as well as validate transactions, across different blockchains. Interoperability of the underlying settlement layers is not achievable in practice, as each blockchain is a separate record of settlements. Nevertheless, "cross-chain bridges" have emerged to permit users to transfer coins across blockchains.[13] Yet most bridges rely on only a small number of validators, whom – in the absence of regulation and legal accountability – users need to trust to not engage in illicit behaviour. But, as the number of bridges has risen (Graph 4.A), bridges have featured prominently in several high-profile hacks (Graph 4.B). These attacks highlight the vulnerabilities to security breaches that stem from weakness in governance.

The striking fragmentation of the crypto universe stands in stark contrast to the network effects that take root in traditional payment networks. Traditional payment networks are characterised by a "winner takes all" property, whereby more users flocking to a particular platform beget even more users. Such network effects stand at the heart of the virtuous circle of lower costs and enhanced trust in traditional platforms. In contrast, crypto's tendency toward fragmentation and high fees is a fundamental structural flaw that disqualifies it as the foundation for the future monetary system.[14]

Despite fragmentation, speculation can induce high price correlations across different cryptocurrencies and blockchains. Attracted by high returns and the expectation of further price increases (Box B), the influx of new users can push up prices even more. As many cryptocurrencies share a similar user base and are tied to similar protocols, there is strong price co-movement. There are important

Bridges across blockchains are rising, and have been at the centre of many hacks Graph 4



[1] See technical annex for details.

Sources: Boissay et al (2022); Comparitech; Defi Llama; BIS.

concerns about what happens to a system that relies on selling new coins when the new inflow of users suddenly slows.

The DeFi decentralisation illusion and the role of exchanges

Despite its name, the DeFi ecosystem shows a tendency towards centralisation. Many key decisions are taken by vote among the holders of "governance tokens", which are often issued to developer teams and early investors and are thus heavily concentrated. Smart contracts tied to real-world events involve oracles that operate outside the blockchain. "Algorithm incompleteness", ie the impossibility of writing contracts to spell out what actions to take in all contingencies, requires some central entities to resolve disputes. Moreover, newer blockchains usually aim for faster transactions and higher throughput by relying on concentrated validation mechanisms. For example, proof-of-stake mechanisms build on a limited number of validators who stake their coins.

Centralisation in DeFi is not without risks. Increasing centralisation of validators gives rise to incentive conflicts and the risk of hacks, also because these centralised nodes are often unregulated.[15] Further, those in charge of an oracle can corrupt the system by misreporting data (the so-called oracle problem). Currently, there are no clear rules on how to vet or incentivise oracle providers.

Centralisation is also present in crypto trading activities, where investors rely mainly on centralised exchanges (CEXs) rather than decentralised ones (DEXs). While the latter work by matching the counterparties in a transaction through so-called automated market-maker protocols, CEXs maintain off-chain records of outstanding orders posted by traders – known as limit order books – which are familiar from traditional finance. CEXs attract more trading activity than DEXs, as they feature lower costs (Graph 5.A).[16] In terms of business model and the way they operate, crypto CEXs are not fundamentally different from traditional exchanges, even though they are not subject to the same regulation and supervision.

CEXs have seen substantial growth since 2020 and have reached volumes that make them relevant from a financial stability viewpoint (Graph 5.B). Moreover,

Box B

Crypto trading and Bitcoin prices

Speculation is a key driver of cryptocurrency holdings,[1] but retail investors may not be fully aware of the risks associated with investments in cryptocurrency. A recent BIS study assembles a novel cross-country database on retail use of crypto exchange apps at a daily frequency over 2015–22, focusing on the relationship between the use of crypto trading apps and Bitcoin prices.[2] The analysis shows that a rise in the price of Bitcoin is associated with a significant increase in new users, ie the entry of new investors, with a correlation coefficient of more than 0.9 (Graph B1.A). A one standard deviation increase in the daily Bitcoin price is associated with an increase of around 90,000 crypto exchange app users. Crypto app users are primarily younger users and men (Graph B1.B), commonly identified as the most "risk-seeking" segment of the population, and potentially motivated by a "fear of missing out". These patterns are consistent with survey evidence on individuals' risk tolerance: younger men are more willing than either women or older male respondents to take financial risks (Graph B1.C).

Quantifying the effect of Bitcoin prices on entry into crypto is difficult because of the possibility of reverse causality. Prices might also increase because of the entry of new crypto exchange app users. To address such concerns, it is possible to focus on specific exogenous shocks when Bitcoin price changes were due to specific factors, such as the crackdown of Chinese authorities on crypto mining activities and the social unrest in Kazakhstan. During each of these episodes, structural changes affected the global price of Bitcoin, independently of the entry of new users in crypto exchange apps. In these cases, the exogenous drop in the Bitcoin price was associated with an average reduction in the number of new app users of 5–10% in the two-weeks following the shocks. Results are further corroborated from a panel vector autoregression model, where a 10% increase in the Bitcoin price leads to a 3% increase in the number of app users.

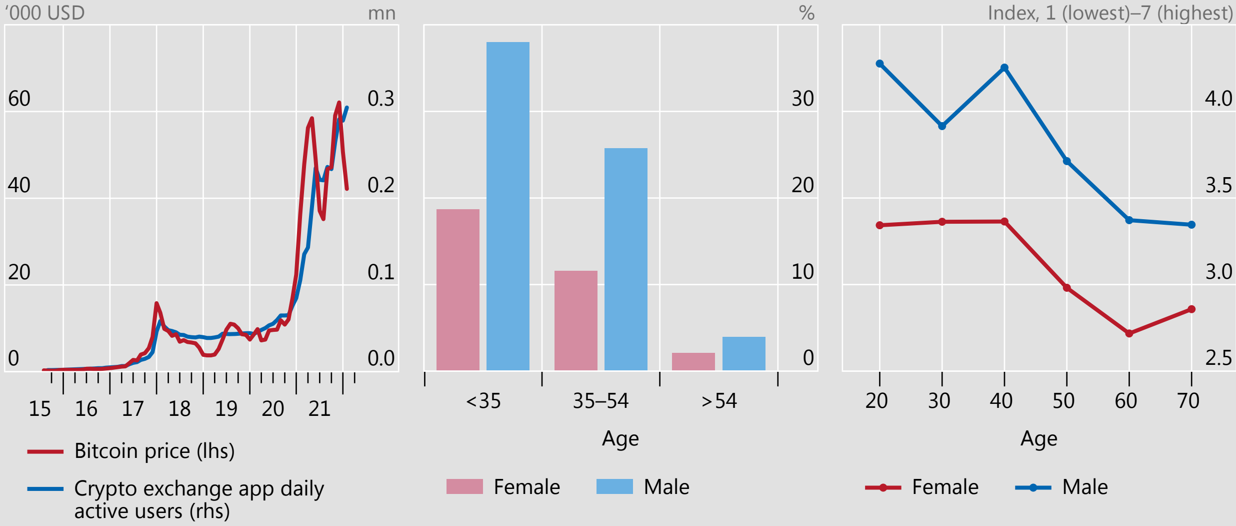
Retail investors are chasing past price increases in a risky strategy

Graph B1

A. Retail cryptocurrency adoption closely follows Bitcoin prices[1]

B. More than one third of crypto exchange app users are young men…

C. …who are often willing to take financial risks[1]

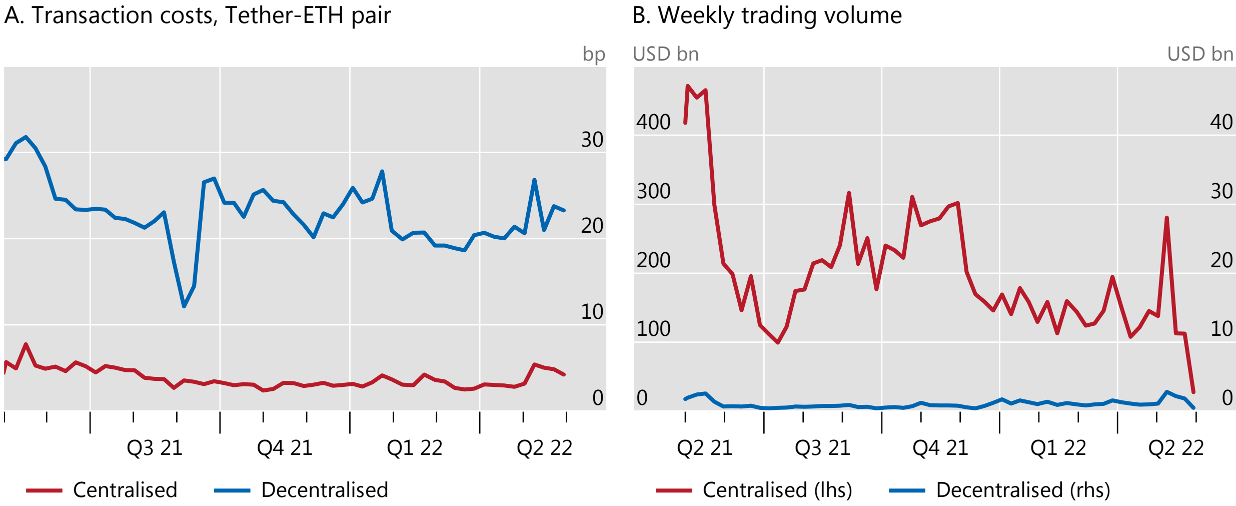


[1] See technical annex for details.

Sources: Auer et al (2022); Federal Reserve Bank of New York, *Survey of consumer expectations*; Sensor Tower.

[1] People invest in cryptocurrencies for different reasons, for example because they distrust domestic financial institutions, for cross-border money transfers or for the potential for pseudo-anonymity – for either legitimate or nefarious reasons. However, one of the main reasons is that cryptocurrencies are seen as investment assets. See Auer and Tercero-Lucas (2021), Foley et al (2019), Hileman (2015), Knittel et al (2019) and Swartz (2020). [2] Auer, Cornelli, Doerr, Frost and Gambacorta (2022).

Centralised and decentralised exchanges: costs and volumes[1] Graph 5



[1] See technical annex for details.

Sources: Aramonte et al (2021); Binance; Coinbase; CryptoCompare; Uniswap; BIS.

trading in CEXs shows a strong tendency towards market concentration: trading volumes in three large CEXs represented around half of the total in the first months of 2022. However, it is generally difficult to gauge the actual size of crypto exchanges, because CEXs hold a significant share of their custodial cryptocurrencies off-balance sheet. For example, the platform Coinbase reported publicly that it had $256 billion of assets on platform (as of end-March 2022) but a balance sheet of only $21 billion as of end-2021. Securities and Exchange Commission staff recently argued that the platform should report both liabilities (obligations to customers) and assets on its balance sheet.[17] In addition, crypto service providers often perform a multitude of services, raising the question whether activities are appropriately ring-fenced and risks adequately managed. For example, together with third-party trading, they undertake proprietary trading, margin lending or token issuance, and supply custody services. Often, transactions involve interactions between on-chain smart contracts and off-chain centralised trading platforms, with the distributed nature of on-chain settlement giving rise to distinct risks as compared with those arising from traditional infrastructure operators.

A balanced assessment of the similarities and differences between the crypto market and traditional finance is a prerequisite for considering appropriate regulatory policies. Some activities of crypto service providers are common features in banks too, although their combination in one entity is not currently common in traditional finance. Moreover, differences in underlying technologies mean that risk features and drivers could differ between traditional finance and the crypto ecosystem.

Regulatory approaches to crypto risks

Regulatory action is needed to address the immediate risks in the crypto monetary system and to support public policy goals.

Above all, authorities need to rigorously tackle cases of regulatory arbitrage. Starting from the principle of "same activity, same risk, same rules", they should ensure that crypto and DeFi activities comply with legal requirements for comparable traditional activities. Stablecoin issuers, for instance, resemble deposittakers or money market funds (MMFs). As such, legislation is needed to qualify these activities and ensure that they are subject to sound prudential regulation and disclosure. For systemically important stablecoins issuers, there must be robust oversight. Where stablecoins are issued by large entities with extensive networks and user data, entity-based requirements will be needed.[18] The recent collapse of the Terra UST stablecoin has highlighted the urgency of the matter.

Second, policies are needed to support the safety and integrity of the monetary and financial systems. Cryptocurrency exchanges that hide the identity of transacting parties and fail to follow basic know-your-customer (KYC) and other Financial Action Task Force (FATF) requirements should be fined or shut down. Otherwise, they can be used to launder money, evade taxes or finance terrorism, and to circumvent economic sanctions. Similarly, banks, credit card companies and other financial institutions that provide entry and exit points between DeFi and the traditional system should require identification from users and perform KYC compliance.

Third are policies to protect consumers. While investors should be allowed to invest in risky assets, including cryptocurrencies, there should be adequate disclosure. This implies sound regulation of digital asset advertising by crypto platforms, which can often be misleading and downplay risks. Practices akin to front-running may require the deployment of new legal approaches.[19] In addition, decentralised platforms cannot, by design, take responsibility in case of fraud or theft connected to the platform, eg as a result of hacks. This stands in the way of providing incentives for the basic disclosure of risks and, as such, new approaches may be needed.[20] This logic also extents to the oracle problem. Sound regulatory rules need to ensure that outside information is not manipulated.

Finally, central banks and regulators need to mitigate risks to financial stability that arise from the exposure of banks and non-bank financial intermediaries to the crypto space. Fast-growing investments in cryptocurrencies by traditional financial institutions mean that shocks to the crypto system could have spillovers. Non-bank investors, family offices and hedge funds have reportedly been the most active institutional investors in cryptocurrencies (Graph 6.A). So far, the exposures of large traditional banks have been limited and direct investments in firms active in crypto markets are still small relative to bank capital (Graph 6.B).[21] That said, bank funding from stablecoin issuers has increased, as bank liabilities such as certificates of deposit form a key part of stablecoins' asset backing.[22] Addressing these risks implies a sound implementation of standards for bank exposures to cryptocurrencies, which should seek to ensure adequate resilience to large and sudden changes in prices or large losses through direct and indirect channels.[23] This may also require prudential regulation of crypto exchanges, stablecoin issuers and other key entities in the crypto system. This does not preclude an innovative approach; for example, supervision could be embedded in these markets, so that it is conducted "on-chain".

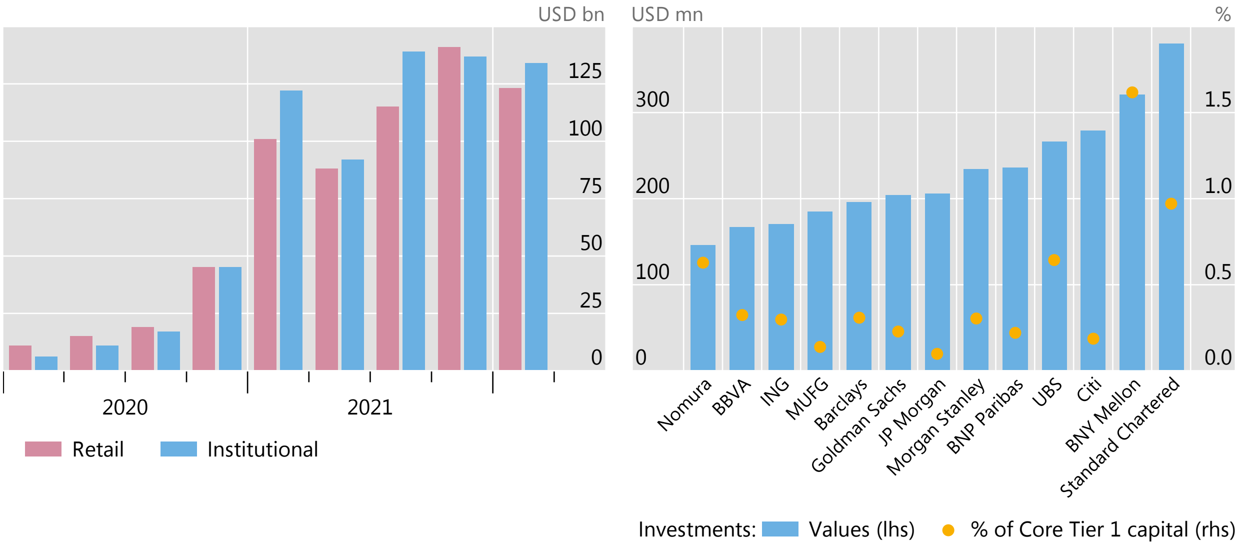
It is essential to fill data gaps and identify entry points for regulation. The growth of the crypto market has led to the proliferation of new centralised intermediaries. Additional entities, such as reserve managers and network administrators, have developed directly as a response to the growth of stablecoins. These centralised entities and traditional financial institutions provide a natural gateway for regulatory responses. These entities could also support the collection of better and more detailed data on DeFi activities, as well as the investor base.

Across all areas of regulation, the global nature of crypto and DeFi will require international cooperation. Authorities may need to actively exchange information and take joint enforcement actions against non-compliant actors and platforms. In some cases, new bodies such as colleges of supervisors may be necessary to coordinate policy toward the same regulated entities operating in different jurisdictions.

Institutional investors play a growing role in crypto | Graph 6

A. Assets on Coinbase are largely institutional, and off-balance sheet

B. Investments of large banks in crypto-active firms are still limited[1]



[1] See technical annex for details.

Sources: Aramonte et al (2021); Auer et al (2022b); Bloomberg; Coinbase.

The BIS is contributing to this international cooperation through discussions in BIS committees such as the BIS Committee on Payments and Market Infrastructures (BIS CPMI) and the Basel Committee on Banking Supervision (BCBS). The BIS is actively engaged in the G20 discussion on the regulation of cryptocurrencies, as coordinated by the Financial Stability Board (FSB). The BIS is also developing applied technological capabilities in this area to inform the international policy dialogue. The Eurosystem Centre of the BIS Innovation Hub is developing a cryptocurrency and DeFi analysis platform that combines on-chain and off-chain data to produce vetted information on market capitalisations, economic activity and international flows.

Crypto's lessons for the monetary system

Overall, the crypto sector provides a glimpse of promising technological possibilities, but it cannot fulfil all the high-level goals of a digital monetary system. It suffers from inherent shortcomings in stability, efficiency, accountability and integrity that can only be partially addressed by regulation. Fundamentally, crypto and stablecoins lead to a fragmented and fragile monetary system. Importantly, these flaws derive from the underlying economics of incentives, not from technological constraints. And, no less significantly, these flaws would persist even if regulation and oversight were to address the financial instability problems and risk of loss implicit in crypto.

The task is not only to enable useful functions such as programmability, composability and tokenisation, but to ground them on more secure foundations so as to harness the virtuous circle of network effects. Central banks can provide such foundations, and they are working actively to shape the future of the monetary system. To serve the public interest, central banks are drawing on the best elements of new technology, together with their efforts to regulate the crypto universe and address its most immediate drawbacks.

Vision for the future monetary system

The future monetary system should meld new technological capabilities with a superior representation of central bank money at its core. Rooted in trust in the currency, the advantages of new digital technologies can thus be reaped through interoperability and network effects. This allows new payment systems to scale and serve the real economy. The system can thus adapt to new demands as they arise – while ensuring the singleness of money across new and innovative activities.

Central banks are uniquely positioned to provide the core of the future monetary system, as one of their fundamental roles is to issue central bank money (M0), which serves as the unit of account in the economy. From the basic promise embodied in the unit of account, all other promises in the economy follow.

The second fundamental role of the central bank, building on the first, is to provide the means for the ultimate finality of payments by using its balance sheet. The central bank is the trusted intermediary that debits the account of the ultimate payer and credits the account of the ultimate payee. Once the accounts are debited and credited in this way, the payment is final and irrevocable.

The third role of the central bank is to support the smooth functioning of the payment system by providing sufficient liquidity for settlement. Such liquidity provision ensures that no logjams will impede the workings of the payment system when a payment is delayed because the sender is waiting for incoming funds.

The fourth role of the central bank is to safeguard the integrity of the payment system through regulation, supervision and oversight. Many central banks also have a role in supervising and regulating commercial banks and other core participants of the payment system. These intertwined functions of the central bank leave it well placed to provide the foundation for innovative private sector services.[24]

The future monetary system builds on these roles of the central bank to give full scope for new capabilities of central bank money and innovative services built on top of them. New private applications will be able to run not on stablecoins, but on superior technological representations of M0 – such as wholesale and retail CBDCs, and through retail FPS that settle on the central bank balance sheet. Central bank innovations can thereby support a wide range of new activities. Because central banks are mandated to serve the public interest, they can design public infrastructures to support the monetary system's high-level policy goals (Table 1, final column) from the ground up.

This vision entails a number of components that require both formal definitions and examples. The section first introduces and explains these components. It next gives a metaphor for what the future system will look like, both domestically and across borders. Finally, it dives into the specifics of reforms to central bank money at the wholesale, retail and cross-border level, before reviewing where central banks stand in achieving this vision.

Components of the future monetary system

The future monetary system builds on the tried and trusted division of roles between the central bank – which provides the foundations of the system – and private sector entities that conduct the customer-facing activities. On top of this traditional division of labour come new standards such as application programming interfaces (APIs, see glossary) that greatly enhance the interoperability of services and associated network effects. Not least are new technical capabilities encompassing programmability, composability and tokenisation, which have so far been associated with the crypto universe.

This vision contains components at both the wholesale and retail level, which enable a number of new features (in bold).

At the wholesale level, central bank digital currencies (CBDCs) can offer new capabilities and enable transactions between financial intermediaries that go beyond the traditional medium of central bank reserves. Wholesale CBDCs that are transacted using permissioned distributed ledger technology (DLT) offer **programmability** and atomic settlement, so that transactions are executed automatically when set conditions are met. They allow a number of different functions to be combined and executed together, thus facilitating the **composability** of transactions. These new capabilities not only permit the expansion of the types of transactions, but also enable transactions between a **much wider range of financial intermediaries** – not just commercial banks. Wholesale CBDCs also work together across borders, through **multi-CBDC arrangements** involving multiple central banks and currencies.

Within the new functions unlocked by wholesale CBDCs, one set of applications deserves special mention – namely, those stemming from the **tokenisation** of deposits (M1), and other forms of money that are represented on permissioned DLT networks.[25] The role of intermediaries in settling transactions was one of the major advances in the history of money, tracing back to the role of public deposit banks in Europe in the early history of central banking.[26] Bank deposits serve as the payment medium, as the intermediary debits the account of the payer and credits the account of the receiver. The tokenisation of deposits takes this principle and translates the operation to DLT by creating a digital representation of deposits on the DLT platform, and settling them in a decentralised manner. This could facilitate new forms of exchange, including fractional ownership of securities and real assets, allowing for innovative financial services that extend well beyond payments.

At the customer-facing, or "retail" level, the enhanced capabilities of the financial intermediaries benefit users in the form of improved **interoperability** between customer-facing platforms provided by intermediaries. Core to this interoperability are APIs, through which users of one platform can easily communicate and send instructions to other, interlinked platforms. This way, innovations at the retail level promote greater competition, lower costs and expanded financial inclusion.

Concretely, FPS and retail CBDCs constitute another core feature of the future monetary system. Retail FPS are systems in which the transmission of a payment message and the availability of final funds to the payee occur in (near) real time, on or as near to 24/7 as possible. Many are operated by the central bank. Retail CBDCs are a type of CBDC that is directly accessible by households and businesses. Both retail CBDCs and FPS allow for **instant payments** between end users, through a range of interfaces and competing private PSPs. They hence build on the two-tiered system of the central bank and private PSPs. Retail CBDCs and FPS share a number of further key features and can thus be seen as lying on a continuum. Both are supported by a **data architecture** with digital identification and APIs that enable secure data exchange, thus supporting greater user control over financial data. By providing an **open platform**, they promote efficiency and greater competition between private sector PSPs, thus facilitating lower costs in payment services. Through **inclusive design** features, both can support financial inclusion for users that currently do not have access to digital payments.

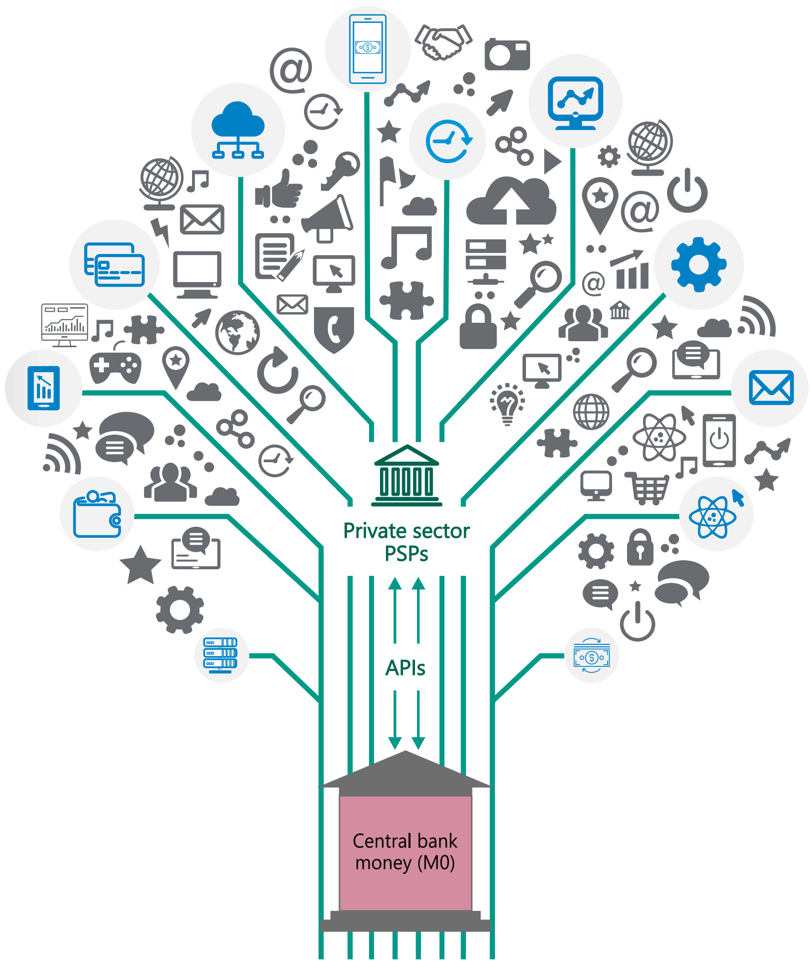
Details of the wholesale and retail components are expanded upon below. For each of these, an advanced representation of central bank money supports private sector services that serve the real economy. The central bank supports the singleness of the currency, and interoperability – the ability of participants to transact in different systems without having to participate in each.[27] This allows network effects to take hold, whereby the use of a service by one party makes it more attractive for others.

A metaphor for the future monetary system

The metaphor for the future monetary system is a tree whose solid trunk is the central bank (Graph 7). As well as exemplifying the solid support provided by central bank money, the tree metaphor expresses the principle of the monetary system being rooted (figuratively speaking) in payment finality through ultimate settlement on the central bank's balance sheet.

The monetary system based on central bank money supports a diverse and multi-layered vibrant ecosystem of participants and functions in which competing private sector PSPs can give full play to their creativity and ingenuity to serve users better. Underlying these benefits is the virtuous circle set off by network effects arising from the data architecture, consisting of digital identity and APIs, that enables interoperability both domestically and across borders.

A metaphor: central bank as tree trunk supporting a diverse ecosystem — Graph 7

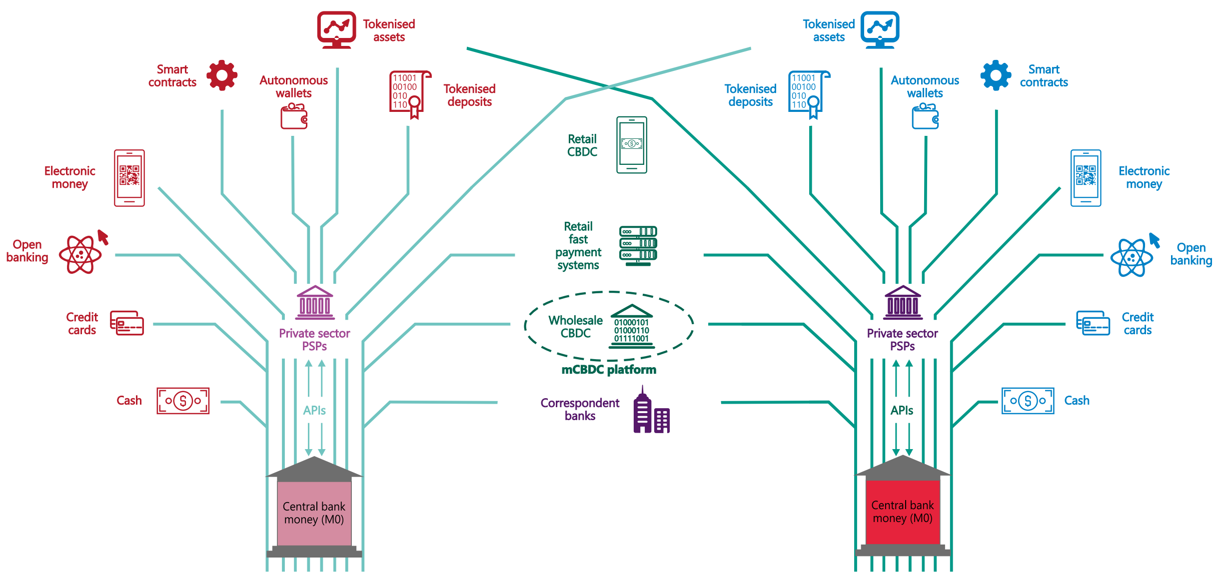


API = application programming interface; PSP = payment service provider.

Source: BIS.

A strong canopy supports the global monetary (eco)system

Graph 8



API = application programming interface; CBDC = central bank digital currency; PSP = payment service provider.

Source: BIS.

Zooming out, the global monetary system can then be compared with a forest, whose canopy facilitates cross-border and cross-currency activity (Graph 8). In the canopy, infrastructures such as multi-CBDC platforms serve as important new elements of the system, as discussed in detail below. The functionality of new platforms in the canopy is ultimately rooted in the domestic settlement layers underneath.

Innovation is not only about the latest fashion or buzzword. Just as a tree cannot sustain a vibrant ecosystem without a solid trunk, getting the basics right is a prerequisite for private innovation that serves the public interest. Ongoing work at central banks is showcasing how public infrastructures can improve the payment system, taking advantage of many of the supposed benefits of crypto without the drawbacks. Wholesale and retail CBDCs, FPS and further reforms in open banking show how central banks can support interoperability and data governance. In fulfilling their public interest mandates, central banks are not working alone but collaborating closely with other public authorities and innovators in the private sector. The following subsections fill in the details of how the system functions, together with concrete examples of the functionalities.

Wholesale CBDCs and tokenised money

A CBDC is a digital payment instrument, denominated in the national unit of account, which is a direct liability of the central bank.[28] Much attention has recently focused on retail CBDCs that are accessible by households and businesses (discussed below). Yet wholesale CBDCs also offer new functions for payment and settlement, and to a much wider range of intermediaries than domestic commercial banks. They could unlock significant private sector innovation across a range of financial services.

Wholesale CBDCs can allow intermediaries to access new capabilities that are not provided by the reserves held by commercial banks with the central bank. These are particularly relevant in permissioned DLT networks, where a decentralised network of trusted participants accesses a shared ledger. As discussed below, decentralised governance is a useful feature of multi-CBDC systems involving multiple central banks and currencies. Yet the functions could in principle be offered in more centralised payment systems. Key are self-executing smart contracts that let participants make their transactions programmable. Transactions thus settle only when certain pre-specified conditions are met. In security trading, such automation can allow payment vs payment (PvP) and delivery vs payment (DvP) mechanisms, meaning that payments and delivery of a security are made only all together or not at all. Such atomic settlement can significantly speed up settlement and mitigate counterparty risk.[29]

One benefit of wholesale CBDCs is that they could be available to a much wider range of intermediaries than just domestic commercial banks. Allowing non-bank PSPs to transact in CBDC could make for much greater competition and vibrancy. New protocols built on wholesale CBDCs could be open source, making the source code freely available for a community of developers to develop and scrutinise. This feature would allow for libraries of protocols that can be used to combine functions, thus facilitating the composability of different functions and enabling new services to be built on top of the programmability function of CBDCs.

By construction, wholesale CBDCs would allow for finality in payments. The mechanics of how finality is attained in permissioned DLT platforms are described in more detail in Box C, but their essence can be explained through the simple analogy with a physical banknote. The recipient of a physical banknote wants to be assured that the note is genuine, not counterfeit. Ensuring that payment is in genuine money in a digital system is accomplished by proving the origin or "provenance" of the money transferred. Crypto proves its provenance by publicly posting the full history of all transactions by everyone. When real names are used, such public posting would violate privacy and would be unsuitable as a payment system. This is where cryptographic techniques such as zero-knowledge proofs (ZKPs) provide a solution. As the name signifies, "proof" denotes that a statement is true, and "zero-knowledge" means that no additional information is exposed beyond the validity of the assertion. Cryptographic techniques allow the payer to prove that the money was obtained from valid past transactions without having to post the full history of all transactions. Depending on the detailed implementation, a "notary" may be needed to prevent the same digital token being spent twice; in many cases, the central bank can play this role. The common theme is that decentralisation can be achieved without the structural flaws of crypto.

As issuers of the settlement currency, central banks can support the tokenisation of regulated financial instruments such as retail deposits.[30] Tokenised deposits are a digital representation of commercial bank deposits on a DLT platform. They would represent a claim on the depositor's commercial bank, just as a regular deposit does, and be convertible into central bank money (either cash or retail CBDC) at par value. Depositors would be able to convert their deposits into and out of tokens, and to exchange them for goods, services or other assets. Tokenised deposits would also be protected by deposit insurance but, unlike traditional deposits, they would also be programmable and "always on" (24/7), thus lending themselves to broader uses in retail payments – eg in autonomous ecosystems. This way, they could facilitate tokenisation of other financial assets, such as stocks or bonds. This functionality could allow for fractional ownership of assets and for the ability to exchange these on a 24/7 basis. Crucially, this could be done in a regulated system, with settlements in wholesale CBDC.

One possible system with tokenised deposits could feature a permissioned DLT platform. This platform records all transactions in tokens issued by the participating institutions, eg commercial banks (representing deposits), non-bank PSPs

Box C

Making use of DLT with central bank money

In a permissionless blockchain used for crypto applications, all transactions are public. Privacy is maintained by hiding the user's real identity behind a private key. In this sense, there is *pseudo-anonymity*.[1] By contrast, a monetary system based on users' real names raises the question of how to safeguard their privacy. Privacy has the attributes of a fundamental human right. Nobody else needs to know from which supermarket an individual buys their groceries. Therefore, a basic task of a decentralised monetary system based on real names is to find a way to ensure both that the ledger is secure without the need for a central authority, while at the same time preserving the privacy of the individual transactions.

One possible route is through permissioned DLT systems. In these systems, only select users that meet eligibility requirements can obtain access. Interactions between system participants are thus invisible to people outside the system. One example is the permissioned DLT system Corda, which is used by private financial institutions (eg for trade finance platforms) and in a number of central bank wholesale CBDC projects, including Projects Helvetia, Jura and Dunbar at the BIS Innovation Hub.

In Corda, updates to the ledger are performed through a validation function and a uniqueness function. Validation, which involves checking that the details of the transaction are correct and that the sender has the available funds, is done by the system participants. In fact, only the participants that are involved in a transaction are responsible for validating it. Checking that the sender has a valid claim to funds does not, however, ensure that they will not attempt to spend those same funds twice. Transaction uniqueness (ie the prevention of double-spending) is ensured by a centralised authority called a "notary". Notaries have access to the entire ledger and hence can ensure that funds being used in a particular transaction are not being used elsewhere. In the case of wholesale CBDCs, a natural candidate for the notary is the central bank, as this institution already plays a similar role in maintaining the integrity of the overall transaction record in centralised systems.

In such permissioned systems, a tension can arise between payment integrity and transactional privacy. Transactional privacy in a peer-to-peer exchange means that only the two participants involved in a transaction can see that it occurs – very much like when one person hands over a one-dollar bill to a friend. In the case of a digital banknote, the validation process performed by the participants requires that the recipient can trace the banknote back to its origin, which in turn entails seeing every one of the banknote's previous holders. In the context of Corda, this is called the "backchain problem". While the system does not allow everyone to see everything, it does allow participants to have a view beyond their own transactions. Solving the backchain problem is an important design problem in central bank CBDC projects. The challenge is to arrange matters so that they can truly emulate paper banknotes and preserve people's transactional privacy.

Recently, system architects have been exploring the use of zero-knowledge proofs (ZKPs) to generate a cryptographic record that a transaction has occurred, without revealing either the identity of a participant or the content of the transaction. ZKPs let one party prove to another that a statement is true without revealing any information beyond that fact. In a payment system, the goal is to prove that the sender of funds obtained those funds through a legitimate chain of transactions, going all the way back to and including the origination of the funds, without sharing any details of these transactions. The goal is achieved by replacing each individual transaction with a ZKP and transferring these proofs, in place of the individual transaction details, during each successive transaction. This technique allows recipients of a digital banknote to know that it can be traced back to its origin, without knowing the details of this banknote's history. Instead of seeing the history of all previous transactions, the verifier, and, if desired, the notary, can observe only a series of ZKPs (see Graph C1).

The ZKP technique is generally understood to be an effective means of generating transactional privacy, but using cryptographic proofs erodes system performance by reducing its speed. Currently, the most popular ZKP systems are the so-called succinct non-interactive arguments of knowledge (SNARKs), succinct transparent arguments of knowledge (STARKs) and Bulletproofs. Each solution has different costs in terms of verification and overall proof time and overall proof size; these are shown in Table C1. Long verification and proof times may reduce transaction throughput to levels that are insufficient to settle typical payment system volumes without adding an unacceptable amount of delay. Researchers are looking for ways to reduce these times.

Zero knowledge proof (ZKP) computation times and sizes

Table C1

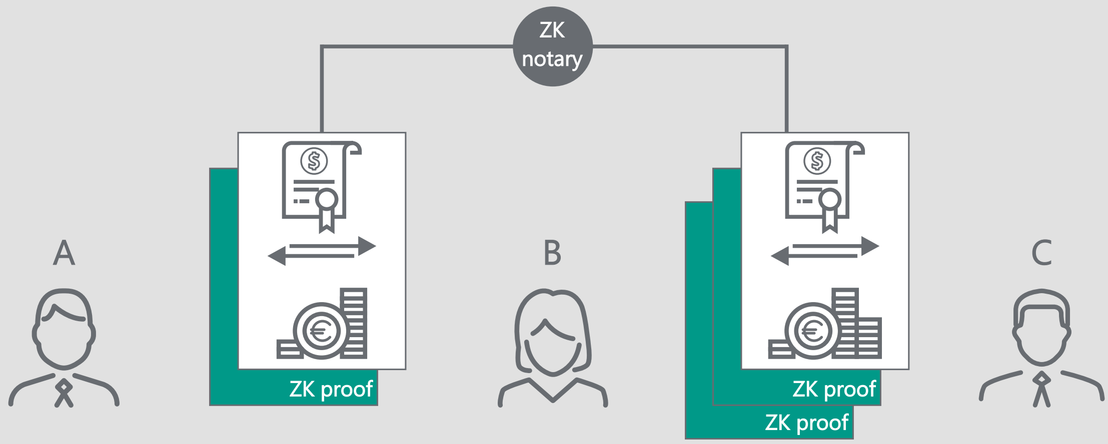
	SNARKs	STARKs	Bulletproofs
Proof time	~2.3 seconds	~1.6 seconds	~30 seconds
Verification time	~10 milliseconds	~16 milliseconds	~1.1 seconds
Size for one transaction	Tx: 200 bytes; Key: 50 MB	45 KB	1.5 KB
Size for 10,000 transactions	Tx: 200 bytes; Key: 500 MB	135 KB	2.5 KB

Sources: Various public research from Zooko Wilcox, Elena Nadilinki and Matter Labs.

Beyond ZKP, transactional privacy can be achieved through other means, such as homomorphic encryption, secure multi-party computation, differential privacy, blind signatures, ring signatures, Pedersen commitments, account abstraction and stealth addresses. Each of these methodologies employs different combinations of trusted setup and/or additional computational overhead. Currently the BIS Innovation Hub is experimenting with stealth addresses, which are one-time use addresses generated by a protocol, with the aim of obscuring the identities of the participants in a transaction.

Backchain solution

Graph C1

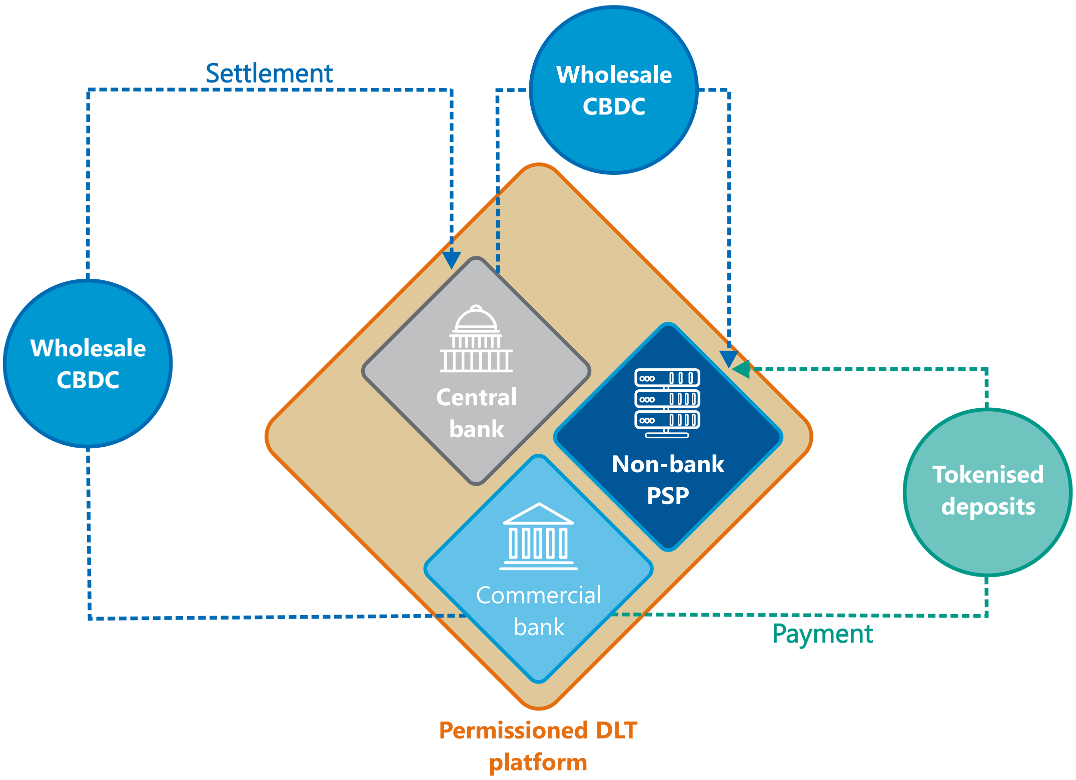


ZK = zero-knowledge.

Sources: Adapted from Annerie Vreugdenhil, ING Bank, CordaCon 2021.

[1] Transactions are not fully anonymous to the extent that, once personal information is linked to a wallet address, all transactions using that address can be traced on the blockchain.

(representing e-money) and the central bank (representing central bank money). Retail investors (depositors) would hold tokens in digital wallets and make payments by transferring tokens across wallets. The settlement of transactions between financial institutions on the DLT platform would rely on the use of wholesale CBDCs as settlement currency. To get a sense of how this would work, consider a depositor who holds a bank's tokens and wishes to make a payment to the holder of non-bank PSP tokens, representing e-money, for instance to pay for a house (Graph 9). Both parties may agree that the payment (green arrow) should occur at the same time the deed to the house is transferred. In the background, to settle the transaction, the bank would transfer wholesale CBDC on the DLT platform to the non-bank PSP (blue arrows). The non-bank PSP would transfer a corresponding amount of new tokens to its customer's wallet. All of these steps could occur simultaneously, as part of a single atomic transaction, executed through smart contracts. In this system, Payment with tokenised deposits settled with wholesale CBDC Graph 9



DLT = distributed ledger technology; PSP = payment service provider.

The green arrows indicate the movement of liabilities and the blue arrows indicate the movement of assets.

Source: BIS, adapted from McLaughlin (2021).

wholesale CBDCs help to settle transactions and to guarantee the convertibility and uniformity of the various representations of money. The same system could also allow for digital representations of stocks and bonds. This would enable end users to easily access (fractions of) these assets in small denominations, 24/7, from regulated providers – and to settle the transactions instantaneously.

Programmable CBDCs could also support machine-to-machine payments in autonomous ecosystems.[31] Autonomous machines and devices increasingly communicate and execute processes without human intervention through the Internet of Things, a network of connected devices. Looking ahead, machines may directly purchase goods and services from each other, and manage their own budget. Their interconnection will increase the need for smart contracts and programmable money. For example, they may be equipped with wallets, charged with a certain budget of digital money. Smart contracts may automatically trigger payments as soon as certain conditions are met, eg the arrival of the goods. This could lead to significant efficiency gains, for example in the goods logistics sector, where transactions often take several days and are still predominantly paper-based. The full potential of these technological developments can be realised only if machine-to-machine transactions are settled instantly, so that any settlement risk is removed. Existing private sector cryptocurrency projects for the Internet of Things are still exploratory and suffer from limits to scalability.[32] They also raise concerns about the stability and convertibility of cryptocurrencies used for payments and would require on- and off-ramp bridges to connect with traditional payment rails. In this respect, the industry could benefit from CBDCs, which could underpin a decentralised system, eg by enabling regulated financial institutions to issue programmable money.[33]

In short, programmability, composability and tokenisation are not the preserve of crypto. The benefits of atomic settlement and open-source protocols are fully compatible with central banks being at the core of the validation process. Yet by relying on central bank money, wholesale CBDCs would benefit from the stability and singleness of the currency that central banks provide. They would also draw on the accountability of the central bank and of regulated intermediaries to society. By supporting innovative private sector services, they would facilitate adaptability so that the system can meet new needs as they arise.

Retail CBDCs and fast payment systems

Retail CBDCs and retail FPS share many similarities. Retail CBDCs make central bank money available in digital form to households and businesses. Bank and non-bank PSPs provide retail-facing payment services. The key difference from retail FPS is that, for CBDCs, the instrument is a legal claim on the central bank. Retail CBDCs are thus sometimes seen as "digital cash" – another form of central bank money available to the public.[34] In retail FPS, many of which are operated by the central bank, the instrument being exchanged is a claim on private intermediaries (eg bank deposits or e-money). Nonetheless, both retail CBDCs and retail FPS build on public data architecture with APIs that ensure secure data exchange and interoperability between different bank and non-bank PSPs. Both feature high speeds and availability, as transfers occur in real time or near real time on a (near) 24/7 basis.

These retail payment infrastructures have already shown their mettle in enhancing efficiency and inclusion in the monetary system. Unlike crypto, which requires high rents and suffers from congestion and limited scalability, CBDCs and retail FPS allow for network effects to lead to a virtuous circle of greater use, lower costs and better services. Because of their explicit mandates, central banks can design systems to meet these goals from the ground up. An open payment system resting on the interoperability of services offered by competing private PSPs can challenge rents in concentrated banking sectors and reduce the payments costs for end users.

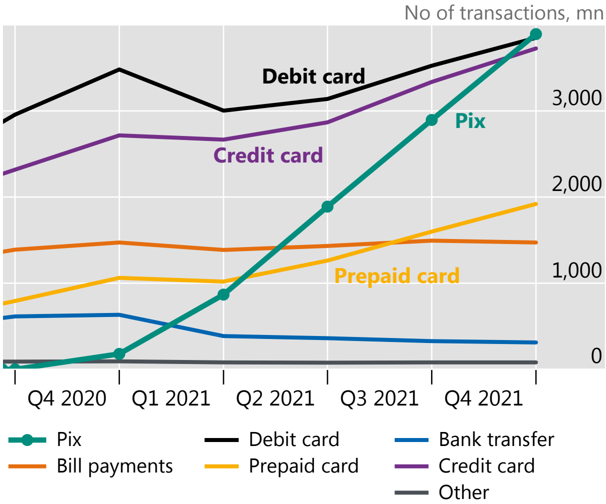
Retail FPS have already made impressive progress in lowering costs and supporting financial inclusion for the unbanked. For example, in just over a year after its launch, the Brazilian retail FPS Pix is used by two thirds of the adult population – with 50 million users making a digital payment for the first time. Powered by innovative products and services offered by over 770 private PSPs, Pix payments have now surpassed credit and debit card transactions (Graph 10.A). The costs to merchants of accepting person-to-business (P2B) payments average one tenth of the cost of credit card payments (Graph 10.B). Equally impressive progress in inclusive, low-cost payments has been made in other economies.[35]

Retail CBDCs could play a similarly beneficial role as retail FPS, while offering additional technological capabilities. For example, Project Hamilton – a joint project by the Federal Reserve Bank of Boston and the Massachusetts Institute of Technology Digital Currency Initiative – has shown the technical feasibility of a CBDC architecture that can process 1.7 million transactions per second – far more than major card networks or blockchains.[36] The project uses functions inspired by cryptocurrencies, but it does not use DLT. In its next stage, Project Hamilton aims to create a foundation for more complex functionalities, such as cryptographic designs for privacy and auditability, programmability and self-custody. The code for the project is open-source and can be scrutinised by any developer, to maximise knowledge-sharing and expand the pool of experts contributing to the code base, including central banks, academia and the private sector.

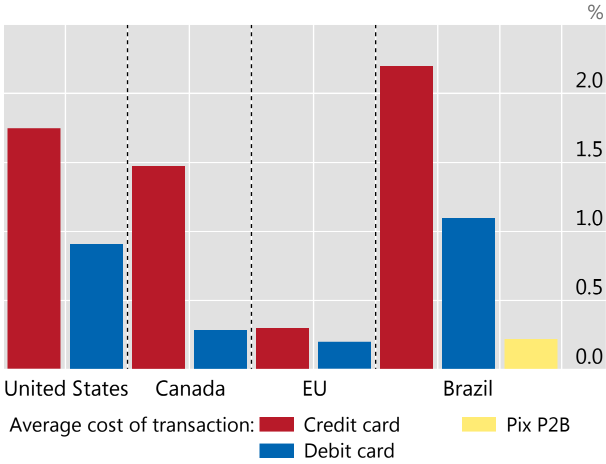
Retail fast payment systems hold promise for rapid adoption and low costs

Graph 10

A. Pix is gaining market share rapidly in Brazil's growing digital payments market…[1]



B. …and enables payment services at very low cost to users and merchants[2]



P2B = peer-to-business

[1] Excluding recurrent utility payments. [2] See technical annex for details.

Sources: Duarte et al (2022); Hayashi and Nimmo (2021); Central Bank of Brazil.

Like retail FPS, retail CBDCs can be designed to support financial inclusion.[37] Many central banks are exploring retail CBDC design features that tackle specific barriers to financial inclusion, for instance through novel interfaces and offline payments (see Box D). For instance, Bank of Canada staff have researched the potential for dedicated universal access devices that individuals could use to securely store and transfer a CBDC. The Bank of Ghana has explored the use of existing mobile money agent networks and wearable devices.[38] Through tiered CBDC wallets with simplified due diligence for users transacting in smaller values, central banks can reduce the cost of payment services to the unbanked, thus fostering greater access to digital payments and financial services. By allowing new (non-bank) entities to offer CBDC wallets, they can also overcome the lack of trust in financial institutions that holds back many individuals in today's system.[39]

Both retail CBDCs and FPS can be designed to protect privacy and grant greater user control over data. In the digital economy, every transaction leaves a trace, raising concerns about privacy, data abuse and personal safety. In addition, the resulting data are of immense economic value – which currently accrues mostly to financial institutions and big techs that collect, store and monetise users' personal data.

The power over data of individual PSPs stems from the fact that, in conventional payment systems, there is no single, complete record of all transactions. Instead, every PSP keeps a record of its own transactions only. While payments across PSPs are made through a centralised system and require instructions to be sent to a central operator, these instructions may involve batched payments or incomplete information about the purpose of the payment. Hence, even the central operator has no complete picture of all payments. Privacy in payments is thus maintained through a fragile combination of isolated record-keeping and the promise of confidentiality by the central operator – but it is not guaranteed. In some cases, data privacy laws give consumers the opportunity to grant or deny third parties consent to use their data. But this option is often difficult to exercise effectively.

Box D

Designing retail CBDCs to support financial inclusion

Many central banks around the world see financial inclusion as a key motivation for their work on retail CBDCs. This is particularly true in emerging market and developing economies (EMDEs), where access to digital payment and other financial services is constrained by several key barriers. These include (i) geographic factors, eg vast territories or islands; (ii) institutional and regulatory factors, such as a lack of identity credentials and informality; (iii) economic and market structure issues, including limited competition and high costs in the financial sector; (iv) characteristics of vulnerability, eg barriers by age, gender, income or disability status; (v) a lack of educational opportunities and financial literacy; and (vi) distrust of existing financial institutions. In many EMDEs, a majority of adults lack access to digital payment options.

A new study draws on the experience of nine central banks around the world in tackling financial inclusion challenges.[1] It finds that some central banks consider CBDCs as key to their mandate as a catalyst for innovation and economic development. Others see CBDCs as a potential complement to existing policies to support financial inclusion. The study argues that, if CBDCs are to be issued, they could be designed with several key design features that directly address barriers to financial inclusion. For instance, they might facilitate low-cost customer enrolment processes, for instance with simplified due diligence, electronic KYC arrangements and tiered wallets, as demonstrated in several live retail CBDC systems (Graph D1.A). Features such as the use of third-party agents help to reach isolated communities and to work around a lack of trust in financial institutions. Central banks can offer a robust, low-cost public infrastructure with a multitude of user interfaces (Graph D1.B). This includes offline functionality, and interfaces that specifically tailor to underserved users. And finally, CBDCs foster interoperability both domestically and across borders, thus contributing to greater competition and lower costs for end users (Graph D1.C).

Inclusive CBDC design features to tackle barriers to financial inclusion

Graph D1

A. Simplified due diligence and tiered know-your-customer (KYC)

B. Multitude of private and public sector user interfaces

C. Interoperability with other means of payment

Source: Boakye-Adjei et al (2022).

[1] Boakye-Adjei et al (2022).

Such a setup implies that consumers may not always know whether their data are being collected and for what purpose.

Proponents of crypto argue that permissionless blockchains return the control over personal data to users, but a system based on pseudo-anonymity and a public ledger introduces severe risks to privacy and integrity. It is also incompatible with a system based on real names, which is required to ensure integrity and accountability.

The data architecture underlying both retail FPSs and CBDCs can give much greater user control over personal data, while preserving privacy and consumer welfare. Indeed, central banks have no commercial interest in personal data, and can thus credibly design systems in the public interest. Data governance systems can ensure user consent, use limitation and retention restrictions.[40] Similar to open banking, these data architectures can also allow users to port data in ways that bring economic benefits to users, for instance when they apply for a loan, want to use financial planning services or in a range of other contexts. Importantly, such a system is based on identification – and this identity information may often be held only by the PSP and not by the central bank. The use of identification also allows financial intermediaries to screen borrowers to assess their creditworthiness, thereby ensuring that scarce capital is allocated to its best use.

In the process, central banks can make use of modern cryptography, which offers solutions to preserve the privacy of users and ensure the security of transactions. This can be achieved for instance through ZKPs, which verify the authenticity of the transaction without revealing its content (Box C). Nonetheless, the system would be based on users' true, verified identities, ie they would transact under their real names. Several central banks also see "electronic cash" in the form of retail CBDC as one potential solution for preserving people's transactional privacy.[41]

Identity-based designs are compatible with integrity in the financial system. With clear mandates and public accountability, systems can be designed to grant law enforcement authorities access to information with the requisite legal safeguards. These approaches are already commonplace in the form of bank secrecy laws and are being considered for retail CBDCs.[42] Importantly, transactions would not be recorded on a public blockchain visible to all. In the corporate space, new corporate digital identity solutions could improve oversight of beneficial ownership, thus reducing fraud, tax avoidance and sanctions evasion.[43] Together with new regtech tools and capabilities inspired by blockchain analytics, there is potential for better tracking illicit activity while making compliance with regulatory frameworks less resource-intensive.

Finally, retail CBDCs and FPS offer opportunities to improve on accountability relative to today's system, and certainly relative to the crypto universe. Indeed, the design of new public infrastructures is not a task for the central bank alone. New systems require public dialogue on the role of the central bank in retail payments. Their operation will require legal mandates to be updated, as well as proper checks and balances and appropriate forms of central bank accountability to society. It is for this reason that many central banks have issued consultations on these initiatives and are promoting dialogue on legal tender and central bank laws.[44] A system built on public infrastructure would also ensure that private service providers are embedded in a sound regulatory and supervisory framework. Unlike in a parallel crypto financial system, parties can be held to account for their actions. In this new ecosystem, there will likely be new private sector business models that do not yet fit with current regulatory frameworks, but experience to date suggests that frameworks can adapt to allow for new types of innovative activity.[45]

Achieving cross-border integration

Integrated global value chains mean that the world is no longer a collection of "island economies", but rather a dense network of interconnections that requires a flexible matrix of money, payments and broader financial services.[46] Wholesale and retail CBDCs as well as retail FPS, can support cross-border integration. The future monetary system will thus be commensurate with the task of providing robust payment and settlement rails that can support economic integration and public interest objectives.

The principles behind the construction of multi-CBDC platforms illustrate the potential for decentralisation to be applied constructively.[47] First, when there is more than one currency involved, more than one central bank needs to take part in the governance of the payment platform. One way to address the governance problem among multiple parties is to adopt decentralisation through a DLT platform. Trusted notaries can manage the shared ledger, and central banks are the natural candidates to take on this task domestically, with shared infrastructure at the global level. Second, since the decentralisation has to be accomplished using real names, rather than using private keys as in cryptocurrencies, safeguarding privacy is an essential design element. Achieving both goals – of respecting privacy while using real names – can be accomplished by using public key cryptography.

There are different models for multi-CBDC platforms, ranging from simply coordinating on standards, through interlinking systems, to a fully shared, common mCBDC platform. On a common mCBDC platform, transfers are recorded on a single ledger in one step, and participants have full real-time visibility of their balances. The settlement process is thus simplified, obviating the need for reconciliation of balances across accounts as in conventional correspondent banking transactions.

A common mCBDC platform creates the opportunity to simplify processes. For example, business rules or conditions can be automated using the smart contract features on a DLT platform. Such process automation reaps efficiency gains both in costs and in transaction time. As mCBDC arrangements involve multiple central banks, each with their own currency, decentralisation can be a constructive feature, and permissioned DLT can play an important role. In addition to the currencies of each central bank in the platform, it could include tokens for other currencies, including international currencies. These platforms have some family resemblance with those used in crypto and DeFi, such as smart contracts and programmability that enable PvP or, in the context of security settlements, DvP across borders.

Linking of public infrastructures across borders is also possible for retail FPS. A recent project at the BIS Innovation Hub showed the potential for linking FPS in different jurisdictions so that payments take seconds rather than days, cutting costs and making fees and exchange rates transparent to senders before they commit to a payment. Achieving these benefits requires coordination in messaging formats and in several key policy areas, but it is technically feasible.[48]

Taking stock of progress toward the vision

Where do central banks stand in achieving this vision of the future monetary system? Substantial efforts are under way, and central banks are working together with one another, with other public authorities and with the private sector to expand the frontier of capabilities in the monetary system.

Globally, a full 90% of central banks recently surveyed are doing some form of work on wholesale or retail CBDCs.[49] A number of wholesale CBDC pilots are under way, often involving several central banks in different jurisdictions. There are three live retail CBDCs and a full 28 pilots. This includes the large-scale pilot by the People's Bank of China, which now counts 261 million users.[50] Meanwhile, over 60 jurisdictions now have retail fast payment systems, with several more planned in the coming years – such as FedNow in 2023.[51] The BIS Innovation Hub is developing mCBDC platforms in partnerships with member central banks. These are Project Jura (with the central banks of Switzerland and France), Project Dunbar (with Singapore, Malaysia, Australia and South Africa), and mBridge (with Hong Kong SAR, Thailand, China and the United Arab Emirates).

A recent stocktake by the Innovation Hub draws lessons from mCBDC experiments to date.[52] These have demonstrated their feasibility from a technical perspective using different experimental designs. They have also shown the potential for much faster, lower-cost and more efficient international settlement, without the need for intermediaries such as correspondent banks. On the retail side, the Innovation Hub, through its Hong Kong, London and Nordic centres is advancing work on cyber-secure architectures, building an open API ecosystem for retail CBDCs, and exploring resilient and offline CBDC systems.

Achieving frictionless payments in the global monetary system requires strong cooperation between central banks, combined with innovation in the private sector. Supporting these efforts is a comparative advantage of the BIS that arises from its mandate for international settlements. Indeed, the BIS has already developed proofs-of-concept and prototypes in near real-world settings. These can help to draw policymakers' attention to the actual issues they are likely to encounter. They also show that cooperation is possible even when central banks take different approaches to some key policy issues.

In sum, central banks are working together to advance domestic policy goals and to support a seamlessly integrated global monetary system with concrete benefits for their economies and end users. The solutions they use will draw on a range of new technologies, some inspired by the crypto monetary system, but grounded in the solid institutional frameworks that exist today. By adapting the system now, central banks will help to make money and payments fit for the decades to come.

Conclusion

The monetary system is a crucial foundation for the economy. Every time households and businesses make payments across the range of financial transactions, they place their trust in the safety of money and payment systems as a public good. Retaining this trust is at the core of central bank mandates.

Rooted in this trust, the monetary system must meet a number of high-level goals to serve society. It must be safe and stable, and key entities must be held accountable for their actions. This way, the integrity of the system is ensured. Fast, reliable and cheap transactions should promote efficiency and financial inclusion, while users' rights to privacy and control over data must be upheld. Finally, in an ever-changing and globally connected world, the system must be adaptable and open.

Recent events have shown how structural flaws prevent crypto from achieving the levels of stability, efficiency or integrity required for a monetary system. Instead of serving society, crypto and DeFi are plagued by congestion, fragmentation and high rents, in addition to the immediate concerns about the risks of losses and financial instability.

This chapter has laid out a brighter vision of the future monetary system. Around the core of the trust provided by central bank money, the private sector can adopt the best that new technologies have to offer, including programmability, composability and tokenisation, to foster a vibrant monetary ecosystem. This will be achieved via advanced payment rails such as CBDCs and retail FPS.

A public-private partnership on these lines could make the monetary system more adaptable and open across borders. A decade hence, users may take real-time, low-cost payments for granted, and payments across borders may be as seamless as the cross-border exchange they support. Consumer choice in financial services should be increased, and innovation will continue to push the frontiers of what is possible.

In all of this, innovation must start from an understanding of the concrete needs of households and businesses in the real economy – and of the policy demands they put on a monetary system. While decentralised technologies such as DLT offer many possibilities, users' needs should stay at the forefront of private innovation, just as the public interest remains the lodestar for central banks.

In both the design of new infrastructures and in regulation, there is an ongoing need for global cooperation between central banks, and indeed a wide range of new stakeholders. Supporting this cooperation will remain a key goal of the BIS.

Endnotes

1. See the BIS Red Book Statistics, which collect data for retail cashless payments in 27 countries, https://stats.bis.org/statx/toc/CPMI.html.

2. See Giannini (2011); Borio (2018)); Carstens (2019).

3. See BIS CPMI (2016); BIS (2021).

4. At present, there are no clear and harmonised guidelines as to who can serve as an oracle, or who is held accountable if a smart contract acts upon incorrect off-chain information. As it is impossible to write ex ante a smart contract that covers every possible contingency, some degree of centralisation is needed to resolve disputes.

5. Security in DLT refers to the robustness of consensus, ie confidence that the shared ledger is accurate. Security can be threatened by malicious actors who compromise the ledger to execute fraudulent transactions, as in a 51% attack (see glossary).

6. See glossary for a definition, Schär (2021) for an in-depth description, and Aramonte et al (2021) and Carter and Jeng (2021) for an assessment of risks and decentralisation. It is noteworthy that, even if DeFi often relies on anonymous and permissionless DLT to achieve decentralisation, permissioned DLT also allows for the use of smart contracts and associated composability (Auer (2022)). In this case, a set of centralised validators are in charge of validating transactions.

7. See Aramonte et al (2021).

8. See Arner et al (2019); Catalini and de Gortari (2021); Frost et al (2021); Gorton and Zhang (2021).

9. See Brainard (2021); Garratt et al (2022).

10. See Allen (2022).

11. See BIS (2018), Auer (2019); Auer et al (2021).

12. The limit is around four transactions per second for Bitcoin and 30 for Ethereum. Possible solutions to the problem of high rents stemming from congestion scalability (eg via "sharding") usually introduce further technological complexity and require a higher degree of centralisation in the governance structure. Further, the sustainability of the incentive structure is not yet fully understood.

13. Bridges can be divided into two main types: "centralised" and "trustless". The differences lie in how bridge transactions are confirmed and how the escrowed assets are stored. In a centralised system, a network of pre-selected validators track token deposits on the source chain, lock them up and mint tokens on the target chain. In a trustless system, anyone can become a validator. For every bridging transaction, validators are selected randomly from a pool to minimise the risks of manipulation. In both cases, the consensus and custodial activities are performed by a limited number of validators.

[14] The need for collateral in many transactions is also detrimental to achieving an inclusive system. Requiring collateral means that it takes money to borrow money. For example, unless users already have sufficient funds in the form of cryptocurrency to post as collateral, they cannot borrow another cryptocurrency on lending platforms. See Aramonte et al (2022).

[15] See IOSCO (2022).

[16] As discussed above, these "gas fees" are designed to compensate validators. Although transaction costs are higher in DEXs, some traders prefer these platforms, in part due to their greater anonymity and interoperability with other DeFi applications.

[17] See SEC (2022).

[18] See CPMI-IOSCO (2021); Carstens et al (2021).

[19] See Auer, Frost and Vidal Pastor (2022).

[20] See Brummer (2022).

[21] See BCBS (2021); Auer et al (2022).

[22] Tether, the largest stablecoin by market capitalisation, reportedly holds half of its reserves in certificates of deposit and commercial paper (currently around USD 25 billion in total), making it a significant investor in this market.

[23] BCBS (2021).

[24] See Carstens (2022); BIS (2021); BIS (2020); CPSS (2003).

[25] See Garratt et al (2022); McLaughlin (2021) argues more broadly for a network of "tokenised regulated liabilities" and of assets.

[26] See Schnabel and Shin (2004, 2018).

[27] See Boar et al (2021).

[28] See BIS (2021).

[29] See Bech et al (2020).

[30] See Garratt et al (2022); McLaughlin (2021).

[31] See Deutsche Bundesbank (2020); Forster et al (2020); Pocher and Zichichi (2022).

[32] See Mercan et al (2021).

[33] See Forster et al (2020) and Bechtel et al (2022) for a discussion of these features.

34 In a CBDC, a payment only involves transferring a direct claim on the central bank from one end user to another. Funds do not pass over the balance sheet of an intermediary, and transactions are settled directly in central bank money, on the central bank's balance sheet and in real time. By contrast, in an FPS the retail payee receives final funds immediately, but the underlying wholesale settlement between PSPs may be deferred (see Carstens (2021)).

35 See BIS CPMI (2021). The Unified Payment Interface in India and Bakong in Cambodia have seen particularly rapid adoption and promotion of financial inclusion goals.

36 See Lovejoy et al (2022). By comparison, major card networks can process several thousand transactions per second, and Ethereum processes 30 per second.

37 See Carstens and Her Majesty Queen Máxima (2022).

38 See Miedema et al (2020); Bank of Ghana (2022).

39 See Gjefle et al (2021). In the United States, distrust of banks and uncertainty around transactions are persistent challenges for unbanked individuals.

40 See Tiwari et al (2022).

41 See CGIDE (2020); ECB (2020).

42 For example, in the Bahamas, the central bank does not have access to the individual identity information of CBDC users and will only share transaction information with law enforcement if a court order is made. See Boakye-Adjei et al (2022).

43 See Leung et al (2022).

44 See eg Board of Governors of the Federal Reserve System (2022); ECB (2020); Bank of England (2022); Bank of Japan (2020); Sveriges Riksbank (2021).

45 For instance, some jurisdictions have defined new roles for private intermediaries in the monetary system, such as payment initiation service providers (EU), third-party app providers (India) or virtual banks (China, Hong Kong SAR, Korea). These often result in new regulatory requirements tailored to newly defined activities.

46 For instance, production of intermediate goods in multiple economies requires an increasing volume of credit. See BIS (2017); Shin (2017).

47 See Auer et al (2021) and glossary.

48 See BIS Innovation Hub (2021).

49 See Kosse and Mattei (2022).

50 See Auer et al (2020), as updated through January 2022.

51 See BIS CPMI (2021).

52 See BIS Innovation Hub (2022); BISIH et al (2021, 2022).

Technical annex

Graph 1: End of week values. Categories comprise the largest nine stablecoins, 59 DeFi coins and 56 other cryptocurrencies. DeFi coins correspond to cryptocurrencies issued by DeFi platforms and with a market capitalisation to total value locked ratio smaller than 50, as reported by DeFi Llama. Total value locked refers to the size of capital pools underpinning DeFi protocols. For more details, see Table A2 from Auer (2022).

Graph 2.A: Outliers larger than 450 Gwei (10^{-9} ETH) are excluded from the graph.

Graph 4.A: Based on bridges and cross-chain protocols.

Graph 5.A: Transaction costs are measured as the relative bid-ask spread, defined as 2*(ask price – bid price)/(ask price + bid price) for Tether-Ether. Centralised is a simple average of crypto exchanges Coinbase and Binance. Decentralised is based on Uniswap. Weekly averages of daily values.

Graph 5.B: Centralised = Binance, Coinbase and FTX; Decentralised = Curve.fi, PancakeSwap (v2) and Uniswap (V2).

Graph 6.B: Companies with a focus on cryptocurrencies technologies. The full list of the companies is available at www.blockdata.tech/blog/general/banks-investing-blockchain-companies.

Graph 10.B: For the United States, Canada and the EU, average of interchange fees on credit and debit cards. Total cost to merchants may be higher.

Graph A1.B: The price corresponds to the low price.

Graph B1.A: Cross-country monthly averages of daily active users.

Graph B1.C: Willingness to take financial risks for US consumers of age 20–79. Weighted average (by survey weights) across respondents. The sample covers the period January 2020–July 2021.

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Glossary

51% attack: When a malicious actor is able to compromise more than half of the validators on the network, the actor can execute fraudulent transactions.

Application programming interface (API): a set of rules and specifications followed by software programmes to communicate with each other, and an interface between different software programmes that facilitates their interaction.

Atomic settlement: instant exchange of two assets, such that the transfer of one occurs only upon transfer of the other one.

Blockchain: a form of permissionless distributed ledger in which details of transactions are held in the ledger in the form of blocks of information.

Central bank public goods: goods and services provided by the central bank that serve the public interest, including payment infrastructures and trust in the currency.

Composability: the capacity to combine different components in a system, such as DeFi protocols.

Consensus: in DLT applications, the process by which validators agree on the state of a distributed ledger.

Cryptocurrency (also cryptoasset or crypto): a type of private sector digital asset that depends primarily on cryptography and distributed ledger or similar technology.

Data architecture: as used here, the combination of identification and application programming interfaces that allows for the secure use of data.

Decentralised applications (dApps): DeFi applications offering services such as lending or trading, predominantly between cryptocurrencies and stablecoins.

Decentralised exchanges (DEXs): marketplaces where transactions occur directly between cryptocurrency or stablecoin traders.

Decentralised finance (DeFi): a set of activities across financial services built on permissionless DLT such as blockchains.

Digital wallet: an interface that allows users to make transfers or otherwise transact in digital money and assets.

Distributed ledger technology (DLT): a means of saving information through a distributed ledger, ie a repeated digital copy of data available at multiple locations.

Gas fees: unit that measures the amount of computational effort required to execute specific operations on the Ethereum network. Gas refers to the fee required to conduct a transaction on Ethereum successfully.

Internet of Things: software, sensors and network connectivity embedded in physical devices, buildings and other items that enable those objects to (i) collect and exchange data and (ii) send, receive and execute commands, including payments.

Level 1: competing blockchains are sometimes referred to as "level 1" networks, to distinguish them from separate off-chain ("level 2") networks that record transactions outside the distributed ledger.

Market integrity: the prevention of illicit activities in the monetary system, such as money laundering and terrorism financing, as well as market manipulation.

Monetary system: the set of institutions and arrangements around monetary exchange. This consists of two components: money and payment systems.

Multi-CBDC arrangements: solutions to make CBDCs compatible, interlink CBDC systems or create a shared system for cross-border, cross-currency CBDC payments.

Non-fungible tokens (NFTs): unique cryptographic tokens that exist on a blockchain and cannot be replicated, used to represent ownership of eg artwork, real estate or other assets.

Open banking: the sharing and leveraging of customer-permissioned data by banks with third-party developers and firms to build applications and services.

Open source: a feature whereby the original source code is made publicly available.

Oracle: a service that provides outside ("off-chain") information for use by smart contracts in a DLT system.

Permissioned DLT: a form of DLT whereby only a pre-defined group of trusted institutions can act as a validating node.

Permissionless DLT: a form of DLT where any participant can act as a validating node, for instance with (permissionless) blockchains.

Programmability: a feature of DLT and other technologies whereby actions can be programmed or automated.

Proof-of-stake: a method by which validators pledge or "stake" coins that are used as an incentive that transactions added to the distributed ledger are valid.

Proof-of-work: a method by which validators compete to perform mathematical computations to verify and add transactions to the distributed ledger.

Pseudo-anonymity: a practice by which users are identified by an address or pseudonym, for instance in a publicly viewable ledger.

Security: in DLT applications, security often refers to the robustness of consensus, ie confidence that the shared ledger is accurate.

Smart contract: self-executing applications that can trigger an action if some pre-specified conditions are met.

Stablecoin: a cryptocurrency that aims to maintain a stable value relative to a specified asset, or a pool or basket of assets.

Token: a digital representation of value in a DLT system. Assets that are represented with a token can be said to be "tokenised". (This is unrelated to the distinction between account-based vs token-based payment instruments.)

Tokenised deposit: a digital representation of a bank deposit in a DLT system. A tokenised deposit represents a claim on a commercial bank, just like a regular deposit.

Total value locked: total value of assets deposited in a DeFi protocol.

Throughput: a measure of the number of transactions that can be processed in a payment system in a given period of time, eg per second.

Validator or validating node: an entity that verifies transactions in a blockchain. In some networks, this role is played by "miners".

Zero-knowledge proof: a cryptographic technique that allows one party to prove to another party that a statement is true without revealing information beyond that fact.

Printed in Switzerland   Werner Druck & Medien AG, Basel

Promoting global monetary and financial stability

Bank for International Settlements (BIS)

www.bis.org
email@bis.org

ISSN 2616-9428
ISBN 978-92-9259-570-8