Global Economic Outlook

September 2021

CNB CZECH NATIONAL BANK

Czech National Bank —— Global Economic Outlook —— September 2021

Cut-off date for data
17 September 2021

CF survey date
13 September 2021

GEO publication date
24 September 2021

Notes to charts

ECB, Fed, BoE and BoJ: midpoint of the range of forecasts.
The arrows in the GDP and inflation outlooks indicate the direction of revisions compared to the last GEO. If no arrow is shown, no new forecast is available. Asterisks indicate first published forecasts for given year. Historical data are taken from CF, with exception of MT and LU, for which they come from EIU.
Leading indicators are taken from Bloomberg and Refinitiv Datastream.
Forecasts for EURIBOR and LIBOR rates are based on implied rates from interbank market yield curve (FRA rates are used from 4M to 15M and adjusted IRS rates for longer horizons). Forecasts for German and US government bond yields (10Y Bund and 10Y Treasury) are taken from CF.

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I. Introduction

As autumn approaches, case numbers have again risen due to the emergence of the Mí variant alongside the Delta variant. Looking at global economic developments, we cannot but notice unusually higher inflation. In two-thirds of G20 countries, inflation is now noticeably higher than the notional 2% ideal, apparently confirming that the Covid crisis, which has led to supply-side problems and deferred consumption, is pushing prices visibly up. The main difference between this and previous crises is that it has affected individual economic sectors unevenly. Unsurprisingly, this was discussed at the Jackson Hole symposium, one of the most important meetings of central bankers and academics (Macroeconomic Policy in an Uneven Economy).

September GDP growth and inflation outlooks for monitored countries, in %

GDP	EA	DE	US	UK	JP	CN	RU
2021	5.0	3.1	5.9	6.7	2.3	8.4	3.8
2022	4.4	4.4	4.3	5.4	3.0	5.6	2.8

Inflation	EA	DE	US	UK	JP	CN	RU
2021	2.2	2.9	4.3	2.2	-0.2	1.3	5.7
2022	1.7	2.0	3.1	2.8	0.5	2.2	4.0

Source: Consensus Forecasts (CF)
Note: The arrows indicate the direction of the revisions compared with the last GEO.

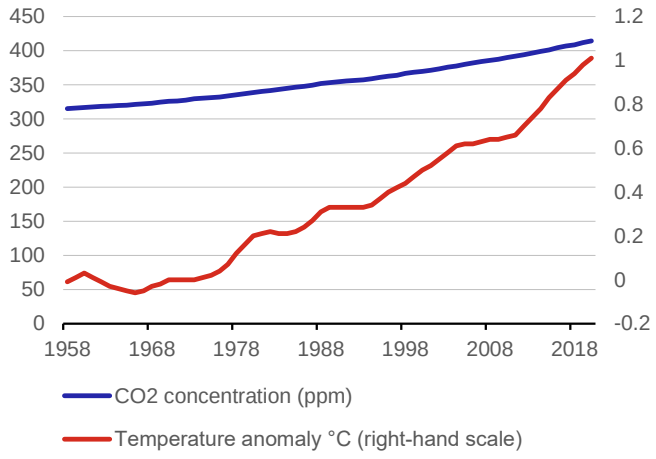
The world's major central banks have yet to respond to rising inflation. US Fed Chairman Jerome Powell explained at Jackson Hole why there was no hurry to tighten monetary policy. According to Powell, the Fed still perceives inflation as temporary and a hike in interest rates may unnecessarily hamper job creation in the USA. However, the Fed seems likely to begin tapering (reducing asset purchases on its balance sheet) before the end of 2021 unless there is a marked deterioration in the epidemic situation. Likewise, the ECB Governing Council left its monetary policy stance (key interest rates, the APP programme and TLTROs) unchanged, but indicated that the pace of purchases under the pandemic asset purchase programme (PEPP) will slow compared with the previous two quarters. However, ECB President Christine Lagarde said this did not constitute the start of tapering, as this will not be discussed before the Governing Council's December meeting.

The September GDP growth outlooks for this year for the advanced countries we monitor are lower than in August, with the exception of the euro area and Russia where there is greater optimism about economic developments. Even so, the economic recovery is solid and GDP in many countries is expected to return to the pre-Covid levels later this year.

The consumer price inflation outlooks were revised up again compared with August for both 2021 and 2022, mainly for advanced economies where strong inflation pressures persist. The exception is again Japan, which will probably be in deflation this year.

According to the August CF, **the US dollar** will weaken against all the monitored currencies at both the one- and two-year horizons, except the Chinese renminbi against which it will strengthen. The CF forecast for **the Brent crude oil price** one year ahead is unchanged from last month at about USD 68/bbl (range: USD 55–81/bbl). **The outlook for market** rates is growing for both the 3M USD LIBOR and 3M EURIBOR, although European rates remain negative.

Climate change as CO_2 concentration and rising temperature



Source: NASA
Note: Temperature anomaly captures the difference in temperature in a given year relative to the 1951-1980 average.

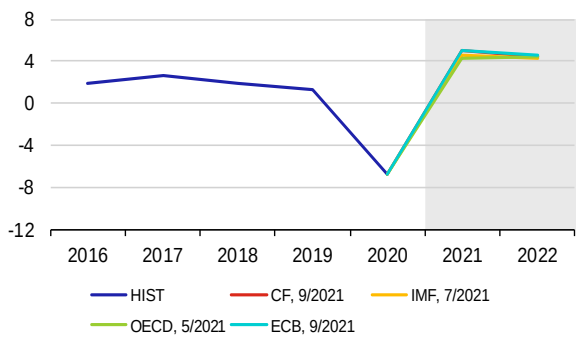
The chart in the September issue shows changes in the earth's climate. This is not only greatly affecting the current direction of economic policy, but is also starting to spill over into monetary policy. Greenhouse gas emissions, especially CO_2, are discussed most. CO_2 concentration in the atmosphere has continued to rise since the last century, accompanied by global warming. In the context of unusually high fiscal deficits to mitigate the effects of Covid-19, several mostly advanced countries are focusing on investment in "green technologies" and reducing emissions. A new carbon tax is also taking shape. This would raise the prices of imported good depending on the level of CO_2 emissions generated during production. The tax is expected to have major long-term inflation potential. This issue contains an analysis "**Modelling the impacts of climate change on the global economy: stagflationary shock looming**". Using model simulations, the authors show that the effects of climate change will be stagflationary overall and will need to be addressed by tighter monetary policy. The results of the analyses show that the choice and timing of global climate policy is decisive for the further impacts of climate change and the related costs.

II.1 Euro area

The Delta variant of the coronavirus spread in all euro area countries during the summer but high vaccination coverage is slowing the increase in case numbers. Large euro area economies are reporting a vaccination rate of over 70% of the adult population as of mid-September, with Spain and France leading the vaccination race. Uncertainty regarding the emergence of this variant is being reflected in worse consumer sentiment but demand remains very robust. Growth has been driven by the services sector after a lifting of the anti-pandemic restrictions. In addition to hotels and restaurants, tourism in Europe also saw an easing of restrictions. By contrast, problems with the supply of materials and components are still affecting industry. Retail sales in the euro area lost momentum in July, due mainly to floods in Germany. By contrast, industrial production grew month on month after repeated declines, the main surprise being the consumer goods segment. The number of cases may rise again in autumn, although broad-based shutdowns are not expected due to high vaccination coverage. Demand may cool slightly, relieving heavily overloaded supply chains.

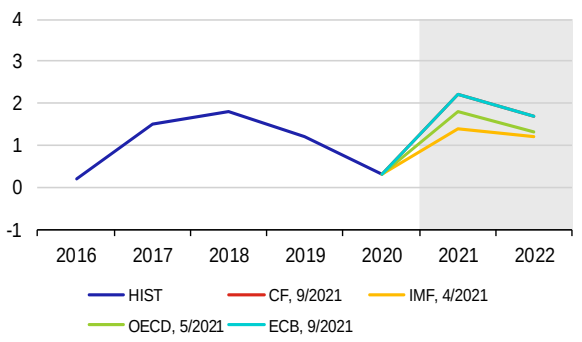
The positive assessment of the euro area economy was reflected in higher expected GDP growth in 2021, but the outlook for 2022 remains unchanged. According to CF, France and Spain will grow by more than 6% but Germany by just 3% in year on year terms. The inflation forecast also moved higher again for both 2021 and 2022. CF panellists predict euro area inflation to stay close to 3% until at least the end of 2021. This will be largely due to inflation in Germany, but expected inflation in Spain have also accelerated. Like the CF forecast, the ECB outlook was also revised, although the central bank is slightly more optimistic about euro area GDP growth in 2022. The persisting problems with the supply of materials and components and an escalation in price pressures create a difficult environment for central bankers' decision-making. The bank has so far announced only a slight recalibration of its instruments towards lower purchases in 2021 Q4. However, the ECB's monetary policy will remain highly accommodative, which is also confirmed by the market rate outlook.

GDP growth, %



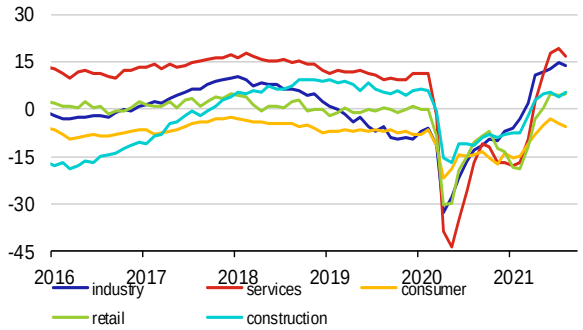
	CF	IMF	OECD	ECB
2021	5.0	4.6	4.3	5.0
2022	4.4	4.3	4.4	4.6

Inflation, %



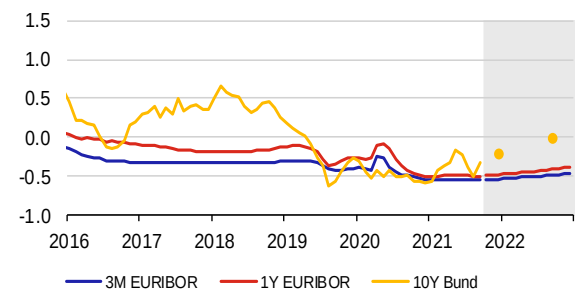
	CF	IMF	OECD	ECB
2021	2.2	1.4	1.8	2.2
2022	1.7	1.2	1.3	1.7

ESI leading indicators



	industry	services	consum.	retail	constr.
6/21	12.8	17.9	-3.3	4.7	5.2
7/21	14.5	18.9	-4.4	4.4	4
8/21	13.7	16.8	-5.3	4.6	5.5

Interest Rates, %



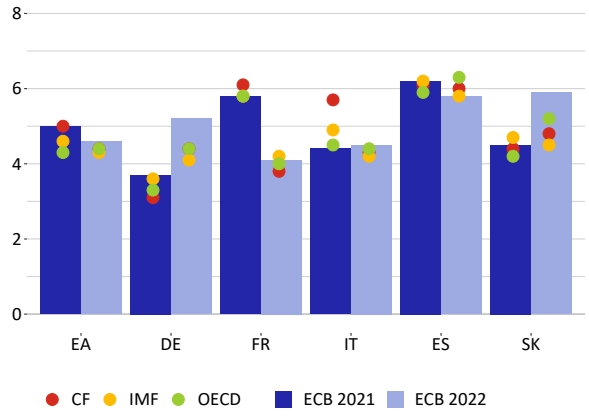
	8/21	9/21	12/21	9/22
3M EURIBOR	-0.55	-0.55	-0.54	-0.49
1Y EURIBOR	-0.50	-0.49	-0.47	-0.41
10Y Bund	-0.50	-0.33	-0.20	0.00

II.2 The euro area in the spotlight – France

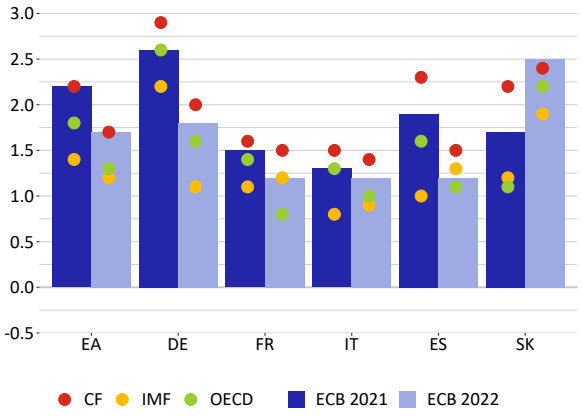
Unlike the other euro area members, France recorded no marked drop in cases during the second wave of the pandemic. Moreover, the short-term spring shutdown did not have much of an effect on its economic performance either. GDP grew only slightly quarter on quarter (by 1.1% after revision) after the lifting of the last measures in Q2, but the economy is still 3% lower compared to the pre-pandemic period. In addition to household consumption, a marked rise in investment was recorded, counteracted by the negative contribution of change in inventories. Although French producers also have to interrupt production due to missing components, the share of industry in France's gross value added is smaller than in other large economies. Shutdowns mainly affected French car producers and the situation did not improve much in Q3 either, according to available reports. The PMI survey also confirms the loss of upward momentum in industry, although demand and orders remain high. Firms still report a willingness to hire new staff and create larger inventories to protect against supply shortfalls. The imbalance between demand and supply has put further upward pressure on prices. However, firms are more concerned about further developments when delayed supplies and higher prices could take their toll. This notwithstanding, consumer confidence remains positive. In addition to very high vaccination coverage, sentiment is also being favourably affected by the government's very strict approach to anti-epidemic measures – from strict Covid certificate requirements to pressure on health care workers to get vaccinated.

According to the CF analysts, the French economy will grow by 6.1% in 2021, slowing to 3.8% in 2022. Household consumption will still be a major driver of growth, but it will be outpaced by expected growth in investment. By contrast, inflation in France will not be as dramatic as in Germany. Inflation will approach 2% in Q3, due mainly to prices of food, energy and services. However, it will reach an average 1.6% in 2021 and 1.5% in 2022. The French central bank expects inflation of 1.8% in 2021 and 1.4% in 2022. According to the new forecast, GDP is also expected to grow this year and the next by 6.3% and 3.7% respectively.

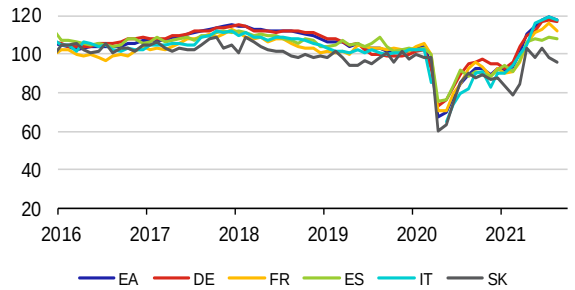
GDP growth in selected euro area countries in 2021 and 2022, %



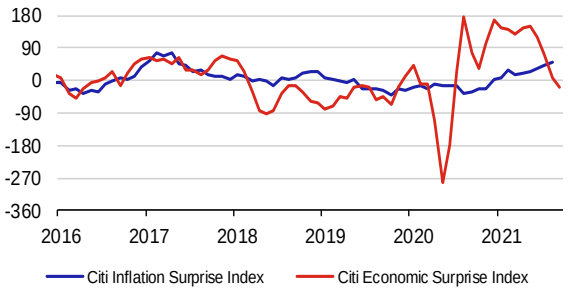
Inflation in selected euro area countries in 2021 and 2022, %



ESI leading indicators



Economic and inflation surprises in the euro area, %



	EA	DE	FR	ES	IT	SK
6/21	117.9	117.2	112.7	107.2	117.9	103.4
7/21	119.0	117.5	116.4	108.9	119.6	97.9
8/21	117.5	117.2	111.9	107.7	117.7	95.8

Note: Inflation expectations based on 5year inflation swap and SPF

	5y5y	SPF
7/21	1.60	1.82
8/21	1.68	1.82
9/21	1.74	1.82

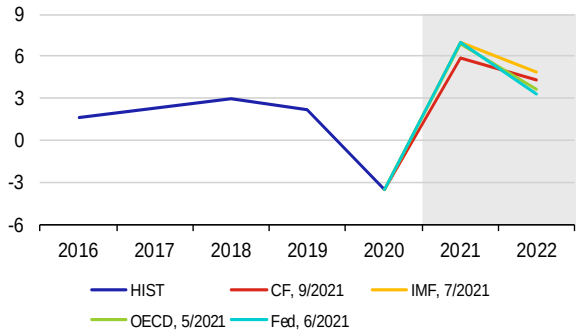
II.3 United States

The USA has entered into a new security pact with the United Kingdom and Australia aimed at strengthening security in the Indo-Pacific region. President Joe Biden is still facing criticism due to developments in Afghanistan. The implementation of Biden's investment plans, which will be discussed in the Congress in the weeks to come, will also be crucial.

The outlook for the US economy has worsened again, with the inflation outlook continuing to rise. Like other economies, the US economy is facing the problem of insufficient production inputs. Here, too, some economists point to possible stagflation scenarios, which pose a risk to the global economy. The new CF outlook expects real GDP to grow by 5.9% this year while in June it had still predicted growth of 6.7%. The GDP growth outlook for next year was also revised downwards (to 4.3%). The inflation outlook has jumped to 4.3% for 2021 and 3.1% for 2022. Annual consumer price inflation stood at 5.2% in August. This was due mainly to growth in the prices of energy (25.0%), which reversed last year's fall, food (3.7%) and services (2.7%). In addition to consumer prices, industrial producer prices are also surging (8.3%), mainly in the finished products category (10.3%). August's labour market figures came as an unpleasant surprise, with only 235,000 jobs created. On the other hand, the unemployment rate fell to 5.2% in August and retail sales are growing (by 1.8% month on month in August). The leading indicators are still optimistic. The PMI in services remains in the expansion band (55.1), as does the industrial PMI (61.1).

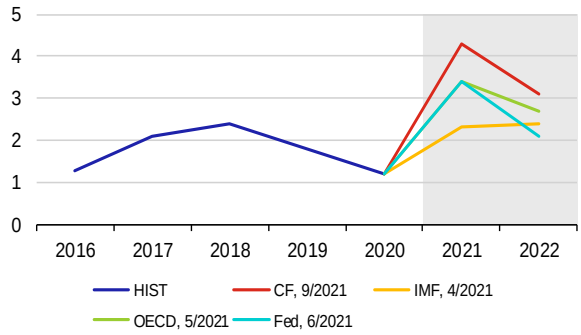
The September Fed meeting will be an important milestone in further monetary policy developments. At the annual Jackson Hole symposium, Chairman Jerome Powell signalled that the support provided via asset purchases may be reduced before the end of this year. Although the coronavirus situation remains unstable and the Delta variant is causing problems mainly for restaurants and on the labour market, retail sales data were a positive surprise.

GDP growth, %



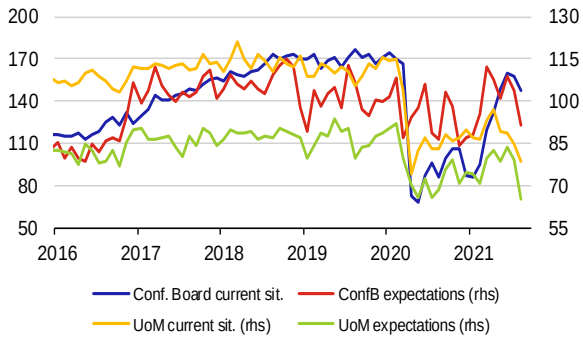
	CF		IMF	OECD	Fed
2021	5.9	↓	7.0	6.9	7.0
2022	4.3	↓	4.9	3.6	3.3

Inflation, %



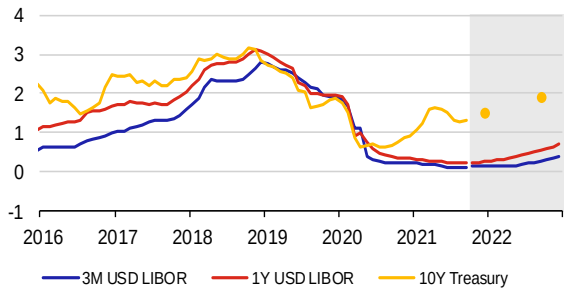
	CF		IMF	OECD	Fed
2021	4.3	↑	2.3	3.4	3.4
2022	3.1	↑	2.4	2.7	2.1

Leading indicators



	ConfB curr.	ConfB exp.	UoM curr.	UoM exp.
6/21	159.6	108.5	88.6	83.5
7/21	157.2	103.8	84.5	79.0
8/21	147.3	91.4	78.5	65.1

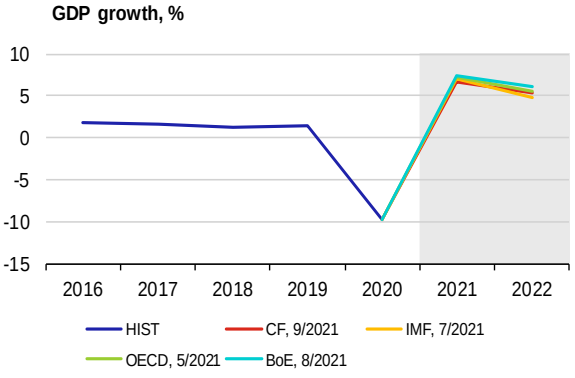
Interest Rates, %



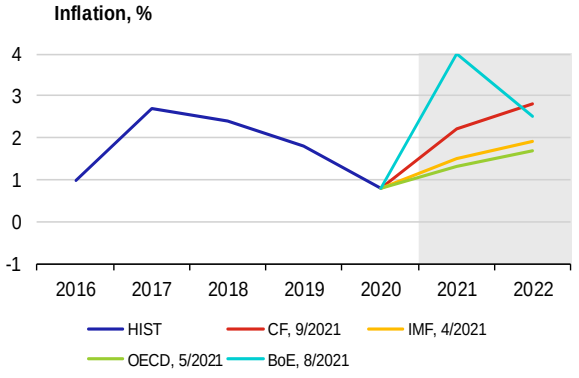
	8/21	9/21	12/21	9/22
USD LIBOR 3M	0.12	0.12	0.17	0.27
USD LIBOR 1R	0.24	0.24	0.26	0.56
Treasury 10R	1.27	1.33	1.50	1.90

II.4 United Kingdom

UK GDP rose by just 0.1% month on month in July after many months of strong growth when the UK economy was making up for the losses caused by the pandemic. The July slowdown in economic recovery was related to the impacts of the "pingdemic", disruptions to supply chains and weaker consumer spending. Sizable risks also stem from the reduction in government supports and labour shortages in many segments amid unprecedented growth in the number of vacancies. The composite PMI is also signalling a significant slowdown in economic recovery. This dropped to its six-month low in August despite remaining in the expansion band (54.8). CF slightly lowered its GDP growth forecast for this year to 6.7%. Annual inflation climbed to 3.2% in August due to food and transport price increases. In September, Boris Johnson's government pushed through a tax hike (national insurance contributions and dividend tax rates will grow from April 2022) to help fund the health service and social care. Moreover, more than six months after Brexit, talks about the future of the problematic Northern Ireland protocol were extended.



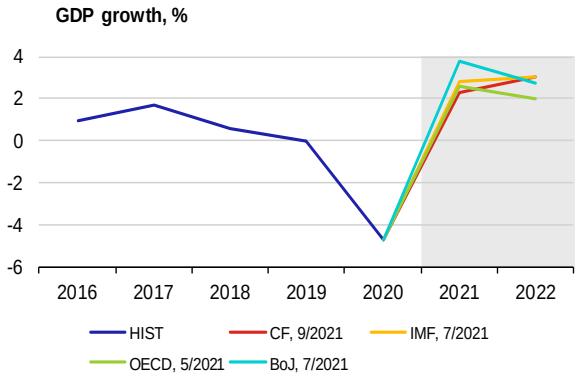
	CF	IMF	OECD	BoE
2021	6.7	7.0	7.2	7.3
2022	5.4	4.8	5.5	6.0



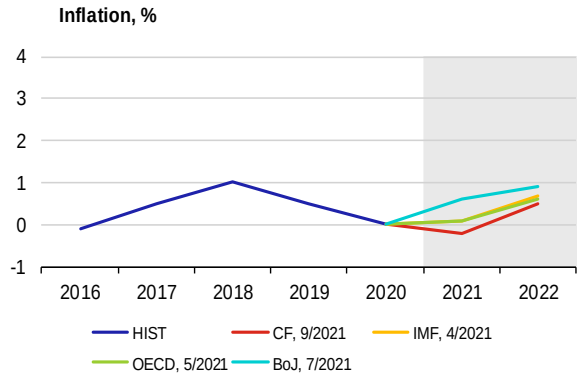
	CF	IMF	OECD	BoE
2021	2.2	1.5	1.3	4.0
2022	2.8	1.9	1.7	2.5

II.5 Japan

After the sudden resignation of Prime Minister Yoshihide Suga, Japan is looking for a successor who will not only lead the country out of the continuing pandemic to economic recovery but will also find solutions to long-term problems. His resignation, after just one year in office, pulled stock indices to 30-year highs, as investors expect Suga's successor, who will be chosen by the ruling party at the end of September, to announce further fiscal stimuli before the autumn elections. The new leader is also expected to respond to long-term, politically divisive challenges, including climate policy, the security threat linked with the rise of China, the state's digitalisation, an ageing population and the related deflation, and chronically weak demand. Revised GDP data for Q2 showed quarter-on-quarter economic growth of 0.5% after a drop of 1.1% in Q1. This exceeded analysts' expectations but lagged behind that of most other major economies.



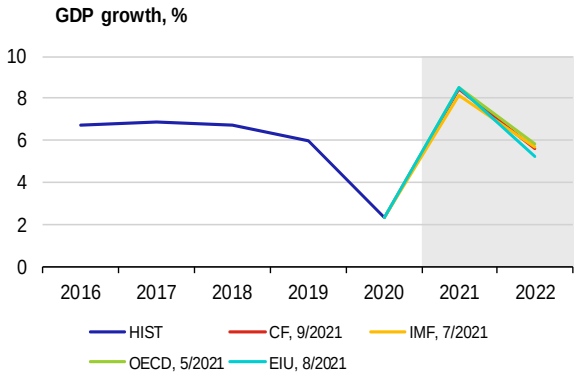
	CF	IMF	OECD	BoJ
2021	2.3	2.8	2.6	3.8
2022	3.0	3.0	2.0	2.7



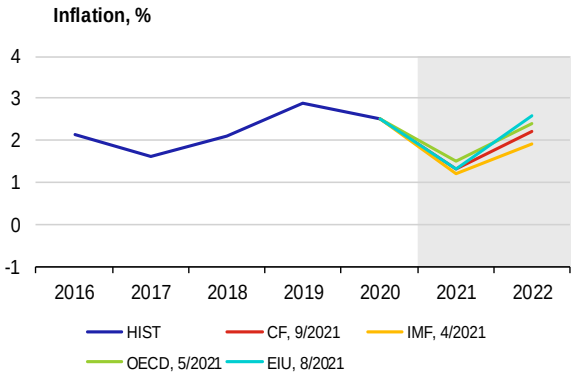
	CF	IMF	OECD	BoJ
2021	-0.2	0.1	0.1	0.6
2022	0.5	0.7	0.6	0.9

II.6 China

Weaker data from both the services sector and industry suggest a continued slowdown in Chinese economic growth in Q3. In August, retail sales reflecting consumer sentiment recorded the slowest growth (2.5%) in the past year, as did industrial production which rose by 5.3%. The Caixin leading indicators in services and manufacturing also fell to more than annual lows in August. According to the CF analysts' current outlook, the Chinese economy will record annual growth of 8.4% in 2021. In addition to an increase in the contribution of net exports, this will mainly reflect a recovery in private consumption. A worsening epidemic situation, to which the Chinese government is responding with strict quarantine measures, is a downside risk to growth. Next year growth in economic activity will slow to 5.6%. Consumer price inflation will average 1.3% this year, which will mainly reflect strengthening domestic demand pressures and growth in commodity prices. Consumer price inflation will accelerate to 2.2% next year.



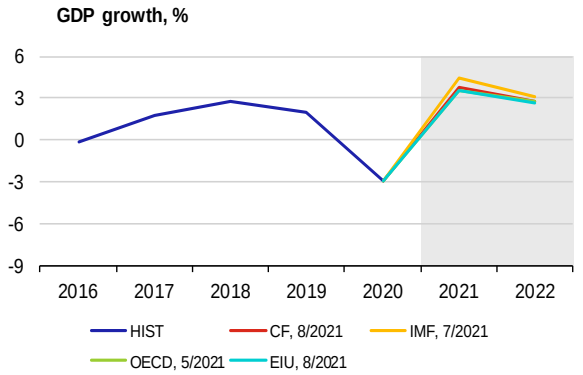
	CF	IMF	OECD	EIU
2021	8.4	8.1	8.5	8.5
2022	5.6	5.7	5.8	5.2



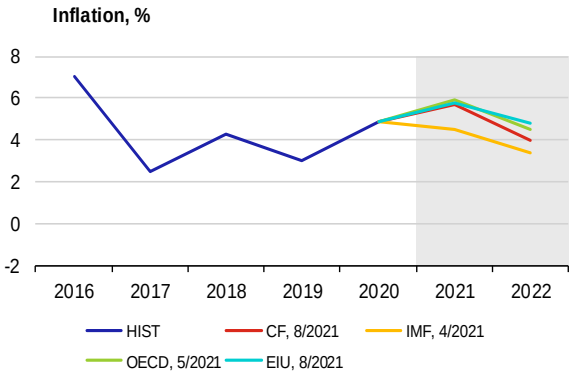
	CF	IMF	OECD	EIU
2021	1.3	1.2	1.5	1.3
2022	2.2	1.9	2.4	2.6

II.7 Russia

Russian GDP growth was better than the first estimate indicated, but the short-term and leading indicators are signalling its slowdown in Q3. According to a revised estimate, the economy grew by 10.5% year on year in Q2. The solid growth was aided by base effects. The growth in industrial production is slowing gradually from its record levels in May to the average of recent years. The leading PMI indicators were in the economic contraction band in August. The PMI in services recorded its first drop to the economic contraction band after a seven-month expansion, while the PMI in manufacturing fell further below the 50-point level for the third month. Inflation accelerated to 6.7% in August. The key interest rate grew to 6.75% due to a further tightening of monetary policy by the Russian central bank, which admits the



	CF	IMF	OECD	EIU
2021	3.8	4.4	3.5	3.5
2022	2.8	3.1	2.8	2.6

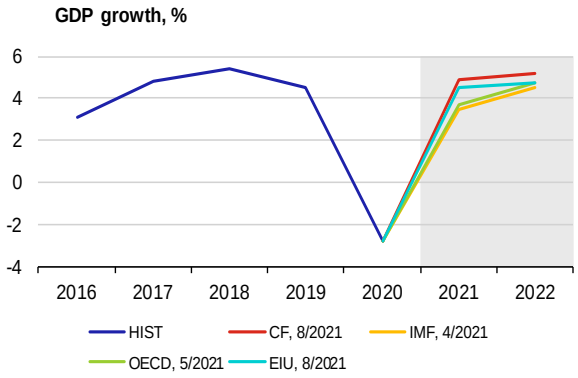


	CF	IMF	OECD	EIU
2021	5.7	4.5	5.9	5.8
2022	4.0	3.4	4.5	4.8

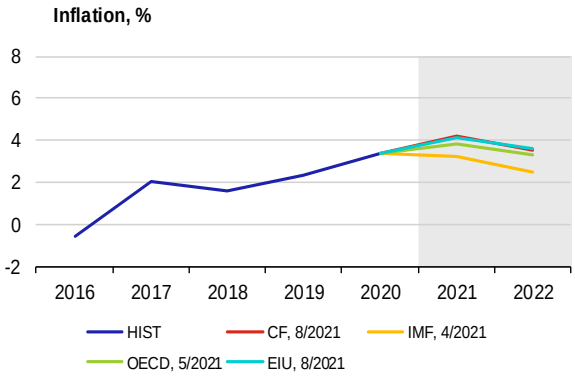
possibility of a further increase in future meetings.

II.8 Poland

At its meeting on 8 September, the Monetary Policy Council of the Polish central bank decided to leave interest rate unchanged despite a further increase in inflation due to growing costs, as predicted in the July forecast. Annual consumer price inflation accelerated from 5.0% in July to 5.4% in August, reaching the highest level since June 2001. In month-on-month terms, consumer prices grew by 0.2% in August (compared to 0.4% in July), mainly reflecting a slower increase in fuel prices. According to a preliminary estimate, GDP grew by 11.1% in Q2, recording the highest increase since 2003. Quarter-on-quarter economic growth accelerated to 2.1% in Q2 from 1.3% in the previous quarter. Business confidence in the Polish economy also grew in August compared to July. On the other hand, industrial production slowed year on year in July (to 9.8% from 18.1% in June) due to slower growth in manufacturing.



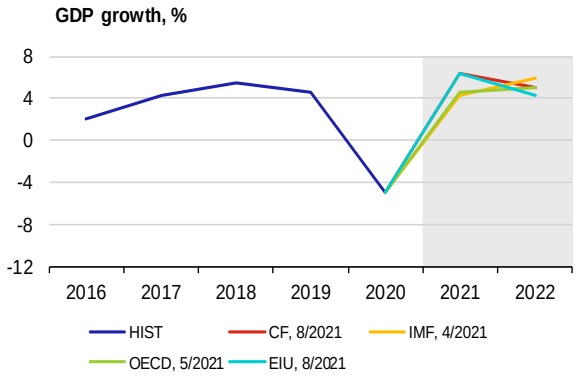
	CF	IMF	OECD	EIU
2021	4.9	3.5	3.7	4.5
2022	5.2	4.5	4.7	4.7



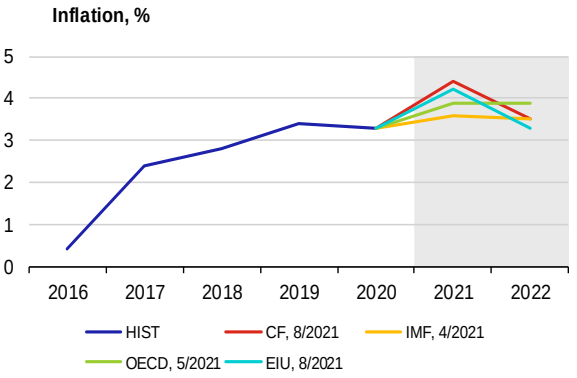
	CF	IMF	OECD	EIU
2021	4.2	3.2	3.8	4.1
2022	3.5	2.5	3.3	3.6

II.9 Hungary

At its meeting on 24 August, the Monetary Council of the Hungarian central bank (MNB) decided to raise the key interest rate for the third consecutive time (from 1.2% to 1.5%). The continued aim of the MNB is to contain persisting inflation pressures, re-anchor inflation expectations and reduce inflation risks amid a strong economic recovery and rapid growth in wages and core inflation (of 3.6% year on year in August). GDP grew by a record 17.9% year on year in Q2 (after a drop of 2.1% in Q1), due mainly to the lifting of anti-epidemic measures and base effects. According to GKI Economic Research, business confidence in the Hungarian economy has grown to the highest level since November 2019 (up from 4.4 in July to 6.1). Annual consumer price inflation accelerated from 4.6% in July to 4.9% in August, remaining well above the upper boundary of the MNB's inflation target (3%±1 pp).



	CF	IMF	OECD	EIU
2021	6.4	4.3	4.6	6.3
2022	5.0	5.9	5.0	4.2



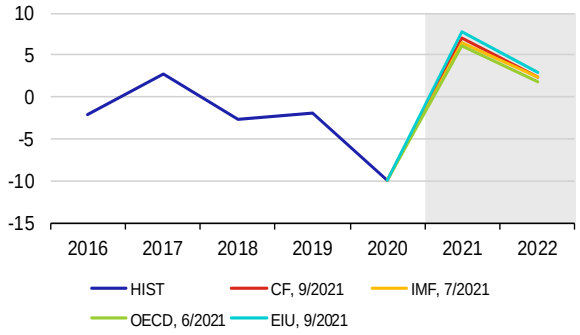
	CF	IMF	OECD	EIU
2021	4.4	3.6	3.9	4.2
2022	3.5	3.5	3.9	3.3

II.10 Argentina

The coronavirus pandemic has exacerbated the problems facing the Argentine economy. Argentina's GDP dropped in the last three years (by 10% in 2020). This year it is expected to grow by 6%–7% despite being hit in May by its strongest pandemic wave, recording new daily cases of around 30,000. The number of new infections is now falling again with more than 42% of population fully vaccinated and at least one dose dispensed to 63% of Argentina's 44 million people. Inflation remains very high and is expected to reach almost 50% this year. Despite this, the central bank has left its rates unchanged since the start of the pandemic and the Argentine peso thus continues to weaken against the dollar. The dollar now costs almost 100 pesos and outlooks suggest a weakening of the peso to ARS 170/USD in two years. Moreover, Argentina continues to apply capital restrictions, while ongoing talks with the IMF about refinancing a USD 45 billion loan are being complicated due to support for government financing by the central bank. The unemployment rate is 10.2% (around 9% before the pandemic) and the country is successfully developing trade, with exports in particular growing.

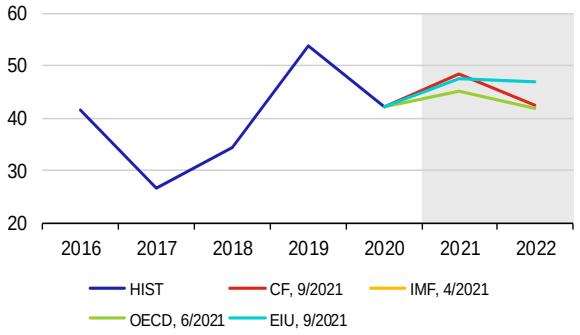
Government expenditure linked with the November elections is also raising inflation. In addition to the widening gap between the official and unofficial exchange rate, there has been a surge in fiscal expenditure to attract voters. Elections were to be held in October but were postponed due to the pandemic. Half of the Parliament and a third of the Senate will be replaced in the elections. Primary elections were held on 12 September. The outcome was largely negative for the ruling left-wing Frente de Todos party (led by Máximo Kirchner) with 30% of votes. By contrast, the coalition of conservatives Juntos por el Cambio gained 42% of votes, which is a good sign for the next round, as representatives of this coalition want to modernise the country and steer politics away from populism. The ruling party had hoped vaccination would have a positive effect on the election outcome but the country's economic situation played a bigger role. President Fernández imposed one of the world's longest lockdowns, which led to a sharp economic downturn and weaker economy. However, the measures were badly enforced and poor Argentines still had to earn a living, leading to a high mortality rate. An illegal birthday party held for President Fernández during the toughest economic lockdown also had a negative effect on voters.

GDP growth, %



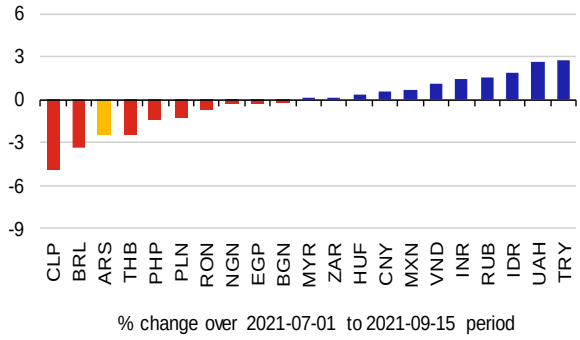
	CF	IMF	OECD	EIU
2021	7.0	6.4	6.1	7.8
2022	2.3	2.4	1.8	2.9

Inflation, %



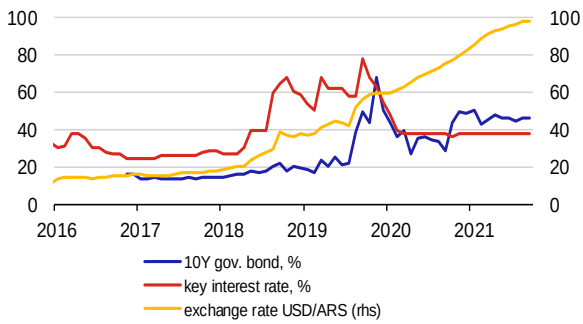
	CF	IMF	OECD	EIU
2021	48.4	n.a	45.0	47.5
2022	42.4	n.a	41.8	46.9

Currency performance vis-à-vis USD



% change over 2021-07-01 to 2021-09-15 period

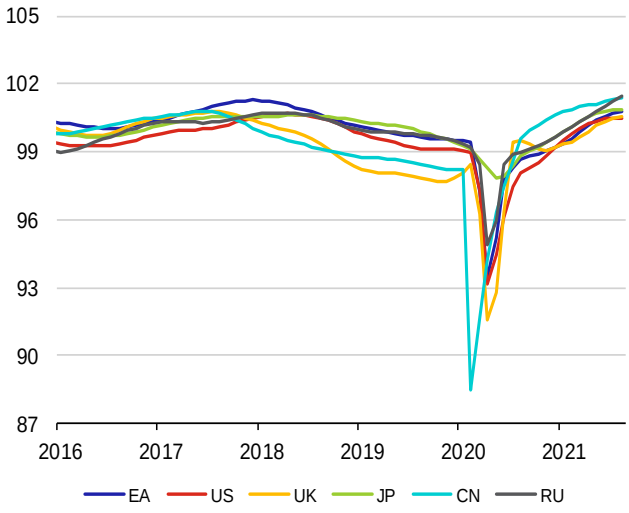
Selected indicators



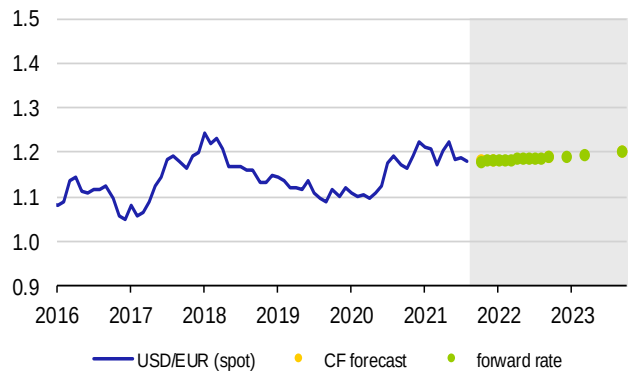
	10Y gov. bond, %	interest rate, %	USD/ARS
7/2021	44.58	38.00	96.69
8/2021	46.07	38.00	97.74
9/2021	46.13	38.00	98.37

III. Leading indicators and outlook of exchange rates

OECD Composite Leading Indicator

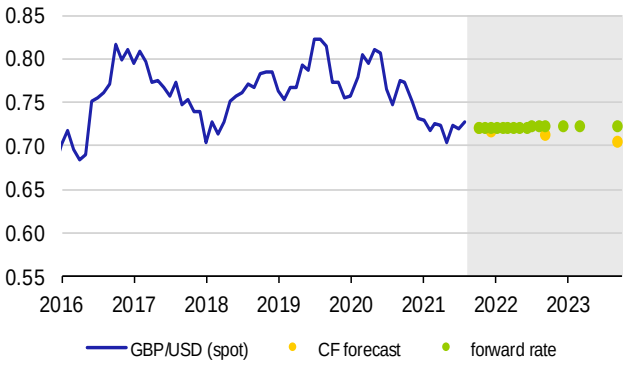


The US dollar (USD/EUR)



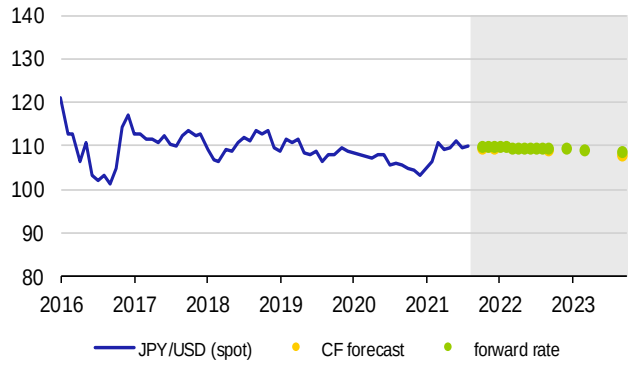
	13/9/21	10/21	12/21	9/22	9/23
spot rate	1.181				
CF forecast		1.185	1.186	1.191	1.204
forward rate		1.182	1.183	1.190	1.202

The British pound (GBP/USD)



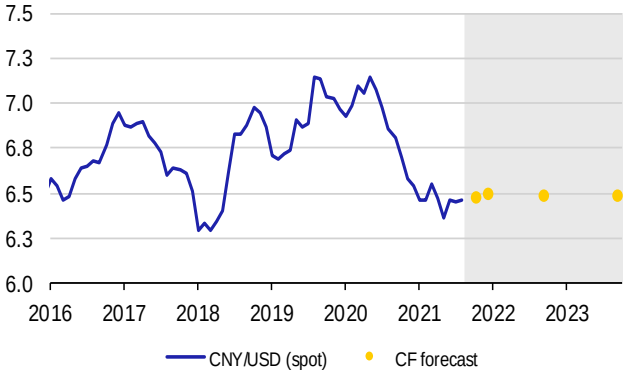
	13/9/21	10/21	12/21	9/22	9/23
spot rate	0.722				
CF forecast		0.722	0.718	0.714	0.706
forward rate		0.723	0.723	0.723	0.723

The Japanese yen (JPY/USD)



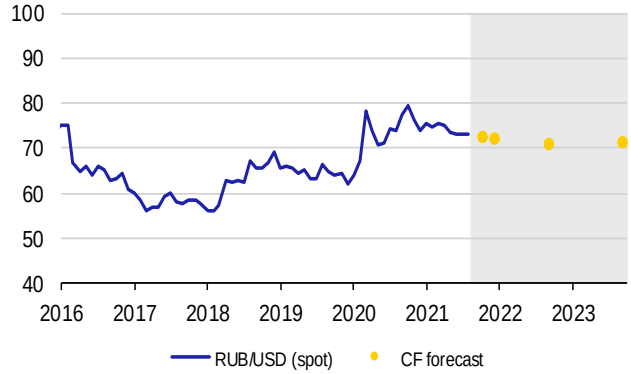
	13/9/21	10/21	12/21	9/22	9/23
spot rate	109.9				
CF forecast		109.5	109.5	109.3	107.9
forward rate		110.0	109.9	109.6	108.7

The Chinese renminbi (CNY/USD)



	13/9/21	10/21	12/21	9/22	9/23
spot rate	6.455				
CF forecast		6.481	6.503	6.493	6.491

The Russian rouble (RUB/USD)



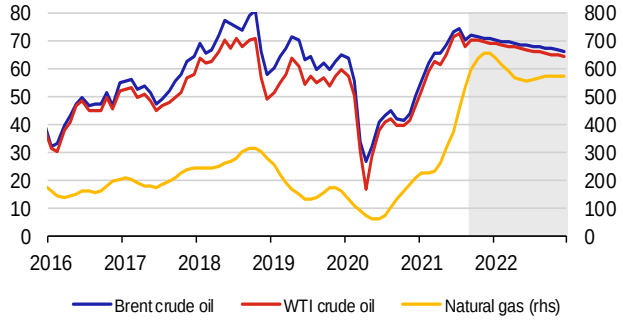
	13/9/21	10/21	12/21	9/22	9/23
spot rate	72.72				
CF forecast		72.64	72.20	71.21	71.41

Note: Exchange rates as of last day of month. Forward rate does not represent outlook; it is based on covered interest parity, i.e. currency of country with higher interest rate is depreciating. Forward rate represents current (as of cut-off date) possibility of hedging future exchange rate.

IV.1 Oil

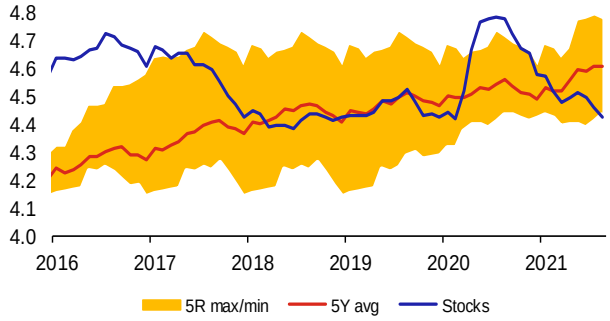
Persisting output outages in the Gulf of Mexico have pushed the price of Brent crude oil back to USD 75/bbl. The deficit in market supply is expected to last until the end of the year. The oil price fell sharply in the first twenty days of August, due chiefly to a more rapid spread of the pandemic which limited demand for oil mainly in Asia. The price was also driven down by a strengthening dollar, weaker economic data from China and an expected increase in output by OPEC+. However, the oil price grew rapidly from USD 65/bbl to above USD 70/bbl in the last decade of August when China had brought the epidemic under control, oil demand in India rose and the dollar weakened. At the end of the month, it was also supported by production outages in Mexico (fire on an oil rig) and in the USA where the effects of hurricane Ida are longer than expected. The IEA estimates that global oil demand fell in July, August and September but should grow strongly in October as the pandemic recedes. However, according to IEA data, global oil output also fell in August and will only stagnate in September, as persistent outages in the Gulf of Mexico will offset the rise in OPEC+ production. Supplies are not expected to grow until October, while the fall in global inventories will persist until the start of 2022. Extraordinary supplies from strategic petroleum reserves in China and the USA should prevent higher oil prices for the rest of the year. The IEA thus predicts the Brent price to be close to USD 72/bbl in the months ahead. Next year, however, global production will accelerate, while oil consumption growth will weaken. The price will thus start to fall in December and average USD 66/bbl in 2022 (USD 63/bbl at the end of the year). The market curve from the start of September is signalling a slightly slower drop in Brent oil prices from the current levels of above USD 70/bbl to USD 66/bbl and USD 63 USD/bbl at the end of 2022 and 2023 respectively. This is broadly in line with the September CF, which predicts a Brent price of USD 67.5/bbl one year ahead.

Outlook for prices of oil (USD/barrel) and natural gas (USD / 1000 m³)

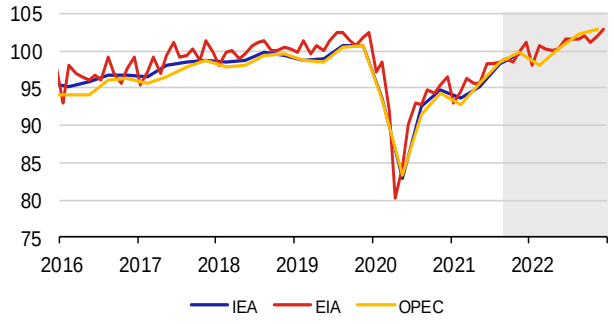


	Brent	WTI	Natural gas
2021	68.40	65.93	432.42
2022	68.22	66.64	579.01

Total stocks of oil and oil products in OECD (bil. barrel)

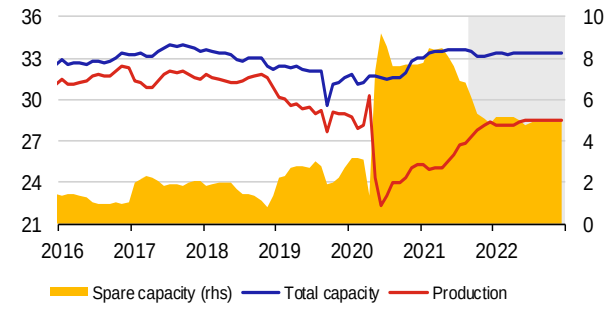


Global consumption of oil and oil products (mil. barrel / day)



	IEA	EIA	OPEC
2021	#N/A	97.37	#N/A
2022	#N/A	101.01	#N/A

Production, total and spare capacity in OPEC countries (mil. barrel / day)



	Production	Total capacity	Spare capacity
2021	26.41	33.39	6.99
2022	28.34	33.33	4.99

Source: Bloomberg, IEA, EIA, OPEC, CNB calculation
Note: Oil price at ICE, average gas price in Europe – World Bank data, smoothed by the HP filter. Future oil prices (grey area) are derived from futures and future gas prices are derived from oil prices using model. Total oil stocks (commercial and strategic) in OECD countries – IEA estimate. Production and extraction capacity of OPEC – EIA estimate.

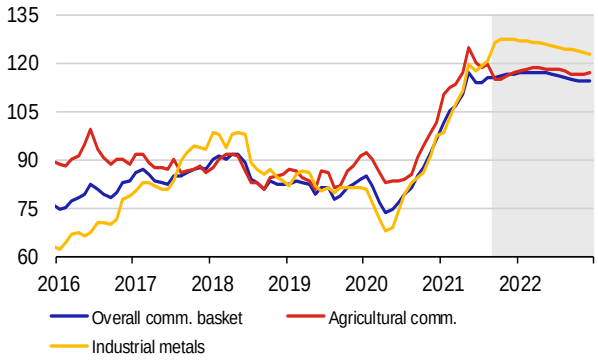
IV.2 Other commodities

The average price of natural gas in Europe hit an all-time high of USD 15.5/MMBtu in August. It rose by a further 24% compared to July, gaining an unbelievable 440% year on year. This was due to still low inventories caused by limited supplies from Russia and Norway. Inventories grew from 57% in July to 67% of total capacity in August but stood at 91% this time last year. Demand for gas in Europe is rising due to high prices of emission allowances and weaker output of wind power, while LNG supplies are heading to Asia where the gas price is even higher. Thermal coal prices rose by a further 11% in August to near the record levels of 2008. This was due to strong demand from power stations in Asia due to above-average temperatures and growth in industrial activity, coupled with a drop in extraction in China, Australia and Indonesia.

The average monthly non-energy commodity price index was at its highest level in around 10 years in May and has fluctuated only slightly below this level since then. A sharper decline was recorded by the food commodity price sub-index, which fell by almost 8% from May to mid-September, due mainly to a drop in maize and soy prices. However, the price of wheat has also been falling since mid-August and the price of pork has also dropped sharply from its June high. By contrast, prices of sugar, coffee and cocoa continue to grow as before.

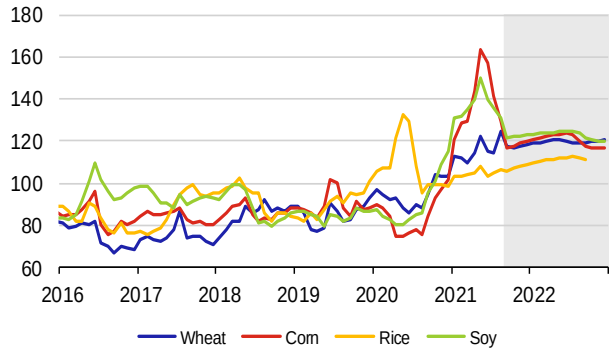
The industrial metals price sub-index saw renewed strong growth in August after a temporary fall in June and July despite a slowdown in global manufacturing. The price of copper fell slightly due to an increase in inventories on the LME but still remains near its all-time high. As for other metals, the price of aluminium rose significantly owing to limited production in China. Prices of nickel and zinc grew at a slower pace. By contrast, the price of iron ore continued to fall sharply in September due to lower steel production in China.

Non-energy commodities price indicies



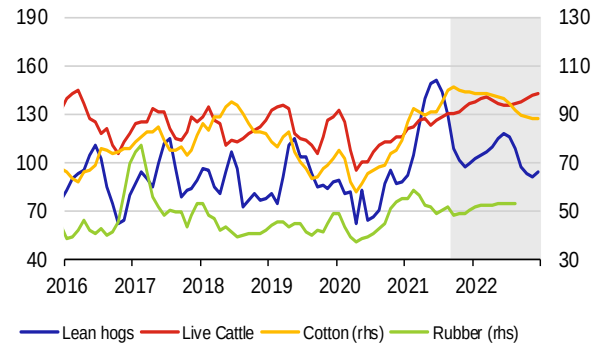
	Overall	Agricultural	Industrial
2021	112.3	116.5	117.0
2022	115.9	117.5	125.0

Food commodities



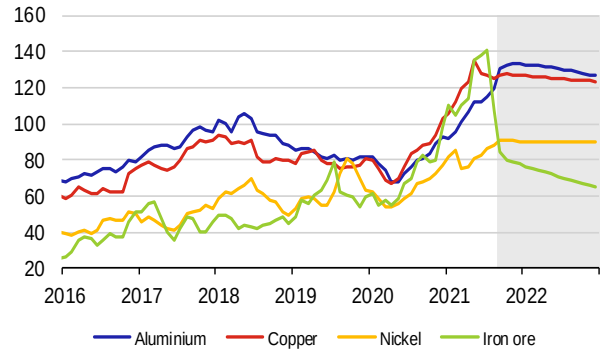
	Wheat	Corn	Rice	Soy
2021	116.3	132.3	105.8	132.0
2022	119.8	120.4	111.4	123.0

Meat, non-food agricultural commodities



	Lean hogs	Live Cattle	Cotton	Rubber
2021	119.7	127.7	94.5	51.6
2022	104.3	138.3	93.7	52.5

Basic metals and iron ore



	Aluminium	Copper	Nickel	Iron ore
2021	115.1	123.7	84.7	106.9
2022	130.0	124.9	89.9	70.6

Source: Bloomberg, CNB calculations.
Note: Structure of non-energy commodity price indices corresponds to composition of The Economist commodity indices. Prices of individual commodities are expressed as indices 2010 = 100.

Modelling the impacts of climate change on the global economy: Stagflationary shock looming [1]

In terms of the frequency and scale of global natural disasters, the stormy summer of 2021 is once again proof that climate change is an indisputable reality. The question is how strong the impacts of climate change will be on individual economies, how these effects will be spread over time and how central banks should respond. The currently available views of central banks, international institutions and other research institutions indicate that these institutions have yet to reach a clear conclusion. Our aim is to use our own model simulations of selected climate scenarios to contribute to the answer. These simulations show that the effects of climate change will be stagflationary overall and will need to be addressed by tighter monetary policy. Furthermore, the results of our analyses demonstrate that the choice and timing of global climate policy is decisive for the further development of the impacts of climate change and its associated costs. In the case of timely implementation of global climate policy, a more significant decline in real economic activity can be avoided at the cost of higher inflation in the short term. We also conclude that policymakers need to prepare for the ever increasing effects of climate change. This will mainly involve building a sufficiently broad analytical framework in the form of modelling tools which are capable of capturing the risks arising from climate change.

Motivation and goal

There is a global consensus that climate change is accelerating and that we need to start preparing for its impacts. Climate change reflects an increase in the average temperature due to the accumulation of mainly carbon dioxide in the atmosphere, which arises from the combustion of fossil fuels (coal, natural gas, oil). This leads, among other things, to changes in weather, with a dramatic increase in the frequency and severity of global natural disasters, such as long periods of drought, floods, cyclones and hurricanes. Climate change therefore presents a very significant global societal risk. So far, government and central bank representatives disagree on the level of action that should be taken to combat climate change. Available studies on the macroeconomic impacts of climate change do not yet provide a clear conclusion on the overall effects of the shock. On the other hand, there is fairly broad consensus that the effects of climate change need to be captured using analytical tools so that they can be incorporated into decision-making processes, for example, when deciding on monetary policy settings.

This article aims to provide an overview and description of the climate change modelling instruments currently available to central banks, including the quantification of the impact of climate change on the global economy. As part of their monetary policy strategy reviews, central banks are newly focusing on the effects of climate change on the economy and the related implications for monetary policy and financial stability. This also includes macroeconomic modelling, which will provide a formal framework. In this context, we present our own simulations of three hypothetical climate scenarios and their impacts on the global economy, including the implications for monetary policy quantified using the NiGEM model.[2]

Economic impacts of climate change and climate protection policies

The risks arising from the impacts of climate change can be divided into "physical" risks, related to extreme weather events, and "transition" risks, reflecting changes in climate policy. Physical risks include different types of natural disasters as well as the negative effects of high temperatures on human health, which may further lead to mass migration and geopolitical conflicts, see Brzoska and Fröhlich (2015) and Rigaud et al. (2018). All these risks will affect aggregate supply and demand. On the supply side, rising average temperatures may, like devastating natural disasters and related forced migration, reduce productivity and labour availability. Extreme events may also physically destroy capital and redirect investment from expanding production to reconstructing capital. Shortfalls in the production factors of labour and capital, along with frequent disruptions to global supply chains and the division of labour, will thus reduce the potential and production capacity of the world's economies. From the demand perspective, physical risks will affect the preferences and behaviour patterns of economic agents, and increased uncertainty will have an adverse effect on private consumption (precautionary savings) and on firms (deferred investment). Physical risks will also have a negative impact on asset prices and the financial sector in general, leading to increasing problems with securing loans, including major challenges, for example, in the insurance sector. Transition risks represent the economic costs of the gradual move towards low-emission economies. They arise as a result of changes in climate policy, unavoidable technological changes that will require major investment, and changes in consumers preferences and habits due to adapting to new conditions. This may involve, for example, new forms of taxation and regulatory restrictions, increases in emission allowance prices, carbon tax, etc. This can trigger a decline in the value of certain corporate assets as well as a decline in corporate profitability in some sectors.

[1] Authors: Martin Motl and Jaromír Tonner. The views expressed in this article are those of the authors and do not necessarily reflect the official position of the Czech National Bank. The authors would like to thank Ian Hurst (NIESR) for valuable discussions on the model simulations.

[2] This is a global econometric model that captures the interconnectedness of all territories of the global economy in detail. For further details on the NiGEM model and its structure, see Hantzsche, Lopresto and Young (2020). The economic impacts of climate change and global climate policy were simulated by extending the NiGEM model to include a climate block.

These changes therefore also pose risks to the financial system, with further impacts on the real economy. A gradual increase in global temperatures will lead to some of the resources from production and innovation being redirected towards climate change adaptation activities. For example, agricultural commodity prices may increase due to lower supply, as part of agricultural land will be used to grow energy crops, leaving less land for the cultivation of agricultural crops.

Climate change from a monetary policy perspective

There is a consensus in recent literature[3] that the effects of climate change on monetary policy settings will be significant. In general, the effects of climate change can be divided into long-term and short-term. In the long term, studies more or less agree that repeated and more frequent natural disasters will lead to lower global economic growth and reduced demand due to higher precautionary savings and hence to a lower long-term natural real interest rate. In turn, weakening demand will mean the need for lower interest rates or the use of unconventional instruments if the zero lower bound is reached. In the short term, both physical and transition risks can also affect inflation in either direction, depending on whether supply or demand effects are predominant (Batten et al. 2020)). We can draw a certain parallel with the coronavirus pandemic where the initial assessment of the effects of the pandemic as anti-inflationary (demand) proved too one-sided. The inflation pressures observed in 2021 are certainly, but not only, the consequence of the "supply-side" nature of the pandemic crisis which provides a clear message for a restrictive monetary policy response, see e.g. Brůha, Motl and Tonner (2021).

However, when it comes to describing the specific direction of the monetary policy response to the effects of climate change in the literature, a high level of caution and ambiguity is exercised. Climate change will affect price stability through its impact on macroeconomic indicators such as inflation, output, employment, interest rates, investment and productivity (ECB (2021)). Furthermore, fiscal policy measures aimed at mitigating the effects of climate change will need to be considered, as they also influence the monetary policy settings. Climate change will also affect the value and risk profile of assets, potentially leading to an undesirable accumulation of financial risks, see NGFS (2019a). Disruptions to financial markets and the associated repricing of climate risks may significantly reduce the price of some assets in the transition to a low-carbon economy. This will result in financial market corrections with spillovers into the real economy and implications for monetary policy settings. The significant effects of climate change on global demand may also increase the likelihood of reaching the effective lower bound on nominal interest rates (NGFS (2019b)). Further studies, such as NGFS (2020a) and Bylund (2020), confirm the above conclusions, although they point out that the scope and spillovers of these impacts remain highly uncertain. These studies highlight that the primary objective of central banks is mostly to ensure low and stable inflation, while other objectives (for example, in the area of climate policy) can only be achieved as long as they are in line with price stability, as central banks cannot arbitrarily broaden their mandate.

Macroeconomic modelling of climate change

Research work[4] on climate change indicates a need to rethink and expand the modelling system of central banks. Allen et al. (2020), for example, address in a study the economic impacts of climate change using different approaches, including a semi-structural global macroeconomic model (NiGEM), a multisector general equilibrium model and a financial micro model (with the reporting of financial ratios and the probability of default at company level). The results of this study show that climate change will reduce GDP in the European Union by 1.0 – 5.0% between 2030 and 2040 (as opposed to the baseline scenario of a "managed" transition to zero emissions in 2050). The study predicts that some sectors, such as oil processing, agriculture and mining, will be significantly affected by climate change.

Many studies[5] call for a stronger policy response to the threat of climate change, including more ambitious efforts to mitigate the causes and impacts of climate change. A theoretical growth model, combining variations in climate variables from their historical averages with labour productivity and long-term economic growth, is being developed as part of the IMF's research presented in Kahn et al. (2019). The main idea is to separate the long-term and short-term effects of climate change on growth, which is essential for designing appropriate mitigation and adaptation policies. As a result of this distinction, the estimated impacts of climate change are significantly higher than in the literature. An increase in the average temperature compared with its historical average of 0.04 degrees a year will reduce global real GDP per capita by 7% by 2100. Without climate change adaptation or mitigation policies, the loss of real GDP per capita will therefore be large, although this will differ significantly from country to country, ranging from 2% to 15% by 2100. Climate change will reduce labour productivity in the long term, slow investment and harm human health.

The impacts on individual sectors can be estimated using multi-regional input and output models. Hebbink et al. (2018) use this type of model to calculate the price impacts of carbon tax on individual sectors, also taking into account the price effects of substitution between energy and primary inputs (capital and labour), as well as substitution between different types of energy. An annual carbon tax increase of EUR 50 per tonne would not have a major impact for the

[3] See Batten et al. (2020), Bylund (2020), Cantelmo (2020), ECB (2021), Economides and Xepapadeas (2018), NGFS (2019b, 2020a).

[4] See Aguilar et al. (2021), Allen et al. (2020), Budnik et al. (2020), Cantelmo (2020), Donadelli et al. (2019), Economides and Xepapadeas (2018), Hebbink et al. (2018), Kahn et al. (2019), Karydas and Xepapadeas (2019).

[5] See ECB (2021), Kahn et al. (2019), NGFS (2019a, 2019b, 2020a).

economy as a whole, leading to a decline in GDP of about 1% over a five-year horizon. However, this tax would have a major impact on a number of carbon-intensive industries. The largest increase in costs would occur in the chemical, metal processing and mining and quarrying sectors, which would greatly reduce their international competitiveness. Estimates of the input-output model suggest that the mitigating effects of energy substitution will only be limited.

The incorporation of a climate block into New Keynesian models may contribute to the study of the effects of climate change on monetary policy. One possible extension of a New Keynesian model is to introduce energy as a production factor into a production function, as in Economides and Xepapadeas (2018). In this model, energy consumption generates emissions that increase the concentration of greenhouse gases in the atmosphere and lead to global warming. Furthermore, the production function is adjusted by a variable in the form of temperature deviation from the pre-industrial period in order to monitor the negative effects of climate change on production. In the model, businesses face two opposing effects: first, higher energy consumption increases economic growth; second, higher energy consumption increases temperature, which leads to more greenhouse gases. Under these assumptions, climate change acts as a new source of shocks to productivity, which increases the persistence of shocks and strengthens the business cycle. The main conclusion of the study is that climate change and the use of instruments to mitigate its effects significantly affect monetary policy settings. In addition, it found that carbon taxes can actually increase economic growth.

Another possible extension of a New Keynesian model is the addition of natural disaster shocks to assess their impact on monetary policy. Cantelmo (2020) contributes to the ongoing debate on the ex ante and ex post macroeconomic effects of natural disasters on the natural real interest rate and inflation. Ex ante, a greater risk of natural disasters increases downward pressure on the natural real interest rate and inflation because of the negative expectations of economic agents. These effects are substantial and non-linear if extreme natural disasters become more frequent. As a result, the natural real interest rate shifts to very low levels and inflation falls well below the target. If a disaster occurs, the effects on the natural real interest rate and inflation may run in both directions depending on whether supply or demand effects are predominant. From the perspective of the central bank, a variety of responses is therefore needed to keep inflation at the target. If supply effects are predominant, the natural real interest rate and inflation pick up temporarily and the central bank raises the monetary policy interest rate. However, if natural disasters have sufficiently strong negative effects on demand, the natural real interest rate and inflation fall and output losses rise. This contribution thus shows the importance of integrating the risk of climate change and natural disasters into the analytical tools used by central banks.

Further research work analyses the impact of carbon taxes, subsidies and the possible uses of budget revenue from carbon taxes. For example, Aguilar et al. (2021) analysed the use of carbon tax revenue as additional government revenue. Their analysis shows that, if used to reduce income taxes, it may have a positive impact on labour supply and ultimately have a positive impact on growth in real GDP and employment. Other studies examine the effect of a suitable combination of carbon tax, subsidies on green energy and asset purchases by central banks on carbon dioxide emissions and economic activity. A combination of measures appears to be important, as carbon taxes alone may have significant effects on economic growth due to higher production costs.

Implications of climate change for financial stability

From a financial stability perspective, there seems to be a consensus[6] on the consequences of climate change in the form of risk accumulation in "dirty" high carbon sectors. This will put downward pressure on asset prices, result in a higher bankruptcy rate, and slow economic growth in these sectors. It will also lead to greater demands and responsibilities for supervisory authorities in the area of financial stability. At the same time, there is a broad consensus that, in the future, central banks should also carry out stress tests which allow for the risks associated with climate change.

The risks associated with climate change are already being reflected in asset prices, and will increase the risk premium and substantially reduce participation in carbon-intensive asset markets. This is the conclusion reached in Karydas and Xepapadeas (2019), which puts forward a theoretical model for two asset types and for macroeconomic and environmental shocks. It first separates "brown assets" (which are related to carbon-intensive activities) and "green assets" (the rest). Furthermore, the model assumes that policy measures are positively correlated with the intensity of environmental disasters. Climate shocks are caused by emissions resulting from the consumption of brown assets, and investors' decisions take into account the fact that portfolios of assets with higher emissions harm the economy.

Risks associated with climate change will lead to a gradual repricing of assets and the value of firms operating in "dirty" industries in favour of firms operating in "clean" sectors. For example, the main assumption of Donadelli et al. (2019) is that "dirty" firms are negatively affected by environmental policies. First, a risk awareness index is created by monitoring the occurrence of the term "climate change risk" both in the literature and on the internet. The results suggest that growing awareness of climate change-related risks since 2005 has led to a decline in the value of firms that rely heavily on fossil fuels compared with other firms in the economy. Furthermore, the economic model examines the consequences of transition risks on asset valuation. In this model, the environmental regulator imposes a carbon tax on the "dirty" sector. The production of "dirty" goods results in greenhouse gas emissions, increases global temperature and harms the production of

[6] See Donadelli et al. (2019), ECB (2021), Karydas and Xepapadeas (2019), NGFS (2019a, 2019b).

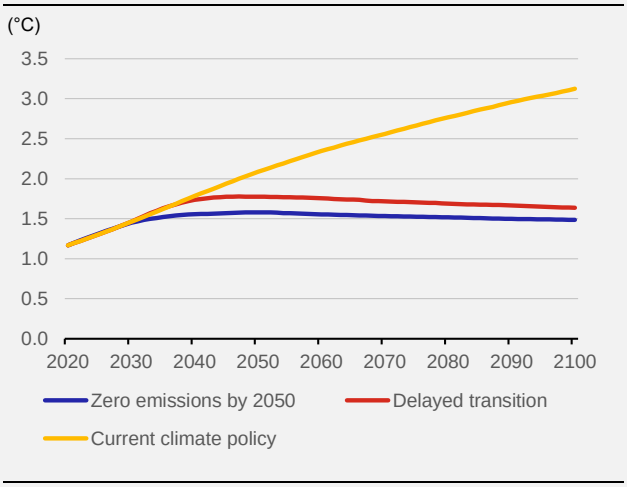
"clean" firms. The model suggests that the transition to a higher carbon tax will harm the "dirty" sector but will ultimately benefit "clean" sectors. Moreover, the model's asset price predictions are consistent with empirical results – "dirty" firms decrease in value in the transition period, while "clean" firms increase in value.

Climate risks must be included in bank stress tests. If transition risks translate into deteriorating macroeconomic conditions, market risk in the form of bank asset repricing and credit risk in the form of deteriorating asset quality must be assumed. These risks constitute separate shock amplification channels. The ECB developed the BEAST macro-micro model described in Budnik et al. (2020) to analyse the impact of these risks. This semistructural model contains a very detailed structure of banks' financial accounts with their reaction functions depending on the balance of the accounts. The macro block consists of a structural panel VAR that identifies structural shocks.

Model scenarios of the economic impacts of climate change

As part of model simulations of the impacts of climate change on the global economy, three hypothetical scenarios for possible future developments have been developed. The first – managed – "zero emissions by 2050" scenario assumes an immediate shift in global climate policy towards zero emission economies by 2050. This scenario corresponds to a target increase in median temperature of 1.5 °C, which is achieved – after its slight overshooting in 2035–2085 – at the end of this century, when the average temperature is expected to fall below this threshold (see Chart 1). Compared with the above scenario, the second – unmanaged – "delayed transition" scenario is characterised by slower implementation of global climate policy leading to a reduction in global CO_2 emissions only after 2030. In the next ten years, this scenario assumes the same level of use of fossil energy sources as in the case of the "current climate policy" scenario. This will lead to a rise in median temperature of almost 1.8 °C in 2045–2055, falling to 1.6 °C by the end of the century following climate action taken after 2030 in line with long-term temperature targets. The third – Hothouse World – "current climate policy" scenario is characterised by the continuation of global climate policy in line with current trends in the use of fossil energy sources and the pace of CO_2 reduction. This scenario is consistent with a gradual increase in the global median temperature, which will already exceed 3 °C before the end of this century. Long-term shock projections for all three scenarios have been obtained using the NiGEM global model and reflect the immediate impacts of climate change, including the implementation of climate policy, on individual world economies until the end of 2050. The model simulations include forward-looking monetary policy responding to deviations of inflation or nominal GDP from the target.

Chart 1 – Median values of temperature profiles for individual climate scenarios compared with 1850–1900



Source: REMIND-MAgPIE-MAGICC global climate model.

The first group of risks modelled are physical shocks, i.e. the direct impacts of climate change, which adversely affect both supply and demand. The negative supply effects of physical shocks have been calibrated for the above three climate scenarios for individual world economies on the basis of Kalkuhl and Wenz (2020) and build on the projected global temperature profiles corresponding to the selected climate scenarios. Global warming and the increasing frequency of heat waves will have a negative impact on human health, leading to reduced availability and productivity of labour. The increasing scale and intensity of natural disasters will lead to total or partial physical destruction of capital in the affected areas. The reduction of the production factors of labour and capital will lead to a decline in the potential of individual economies and thus to a decrease in overall global production capacity (supply). On the demand side, physical shocks will have a negative effect, especially on private consumption and investment, the decline in which is derived from the negative supply effects on real economic activity. In all, the effect of physical shocks will foster a decline in GDP, whereas in the case of price developments the inflationary effects resulting from supply disruptions and the anti-inflationary effects reflecting the decline in demand act in opposite directions. The simulation of physical shocks assumes an endogenous monetary policy response for all three climate scenarios.

The second group of risks modelled includes transition shocks, i.e. indirect impacts reflecting the decisions of global climate policy makers. Transition shocks for the individual global economies (see Chart 2) were calibrated using the outputs of the REMIND-MAgPIE global climate model[7] only for the "zero emissions by 2050" and "delayed transition"

[7] The Regional Model of Investment and Development is a model covering individual regions of the world economy with a focus on the energy sector and implications on the global climate system. More information about the REMIND model and its structure can be found at https://www.pik-potsdam.de/en/institute/departments/transformation-pathways/models/remind. The outputs used for the model simulation itself

climate scenarios, as the "current climate policy" scenario does not consider transition impacts. As regards transition shocks, the model simulation assumes for both climate scenarios an increase in carbon tax, a decrease in the energy intensity of production, a decrease in the consumption of fossil energy sources (coal, oil, gas) and an increase in the consumption of renewable energy sources.

A global climate policy designed to reduce air pollution by increasing the carbon tax will lead to an increase in the costs associated with the use of fossil energy sources (coal, gas, oil). Pressure to reduce the share of fossil inputs in

Chart 2 – Climate assumptions regarding transition shocks for model simulations performed using the NiGEM model

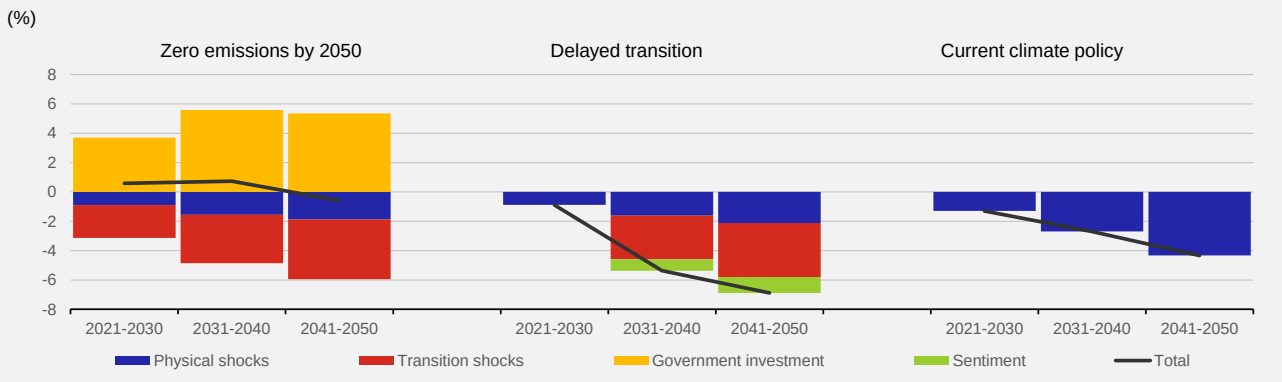
Source: REMIND-MAgPIE global climate model.
Note: Deviations in % from the "current climate policy" scenario, which is based on similar assumptions as the climate-neutral baseline scenario.

are based on combining the REMIND model with the MAgPIE model (Model of Agricultural Production and its Impacts on the Environment). The REMIND-MAgPIE climate model projections are available until the end of 2100 and only at five-year intervals. Therefore, for input into the NiGEM model, the missing years were extrapolated and spread over quarters to obtain country-specific impacts on macroeconomic variables, while limiting the length of the forecast horizon until the end of 2050.

production will result in lower productivity (a negative supply shock) and will therefore be an additional inflationary factor. A fall in consumption and fossil commodity prices will have the opposite effect on inflation, while the consumption of renewable energy sources preferred by global climate policy will grow over time. Carbon tax revenue will have a positive effect on national public budgets in the form of an additional source of revenue. The simulation of transition shocks for the "zero emissions by 2050" and "delayed transition" scenarios envisages an endogenous monetary policy response, which is, overall, an inflationary mix of cost and negative supply shocks with negative effects on GDP in both cases. However, in the next step, the assumptions of the two scenarios already diverge, as the model simulation of the "zero emissions by 2050" climate scenario assumes that fifty per cent of the revenues generated by the carbon tax increase from the start of the forecast horizon will be reinvested in the economy by governments. Furthermore, this simulation assumes that the central bank does not react to this partial positive demand shock by tightening monetary policy so as to avoid implementing contradictory economic policies in response to the inflationary effects of government expansionary fiscal policy. The remaining half of the revenue from the carbon tax will be used to reduce government debt. In the "delayed transition" climate scenario, which involves a ten-year delay in the carbon tax increase and slower growth in the tax in subsequent years and thus lower revenue compared with the previous scenario, the additional revenue goes directly to national government budgets via endogenous modelling mechanisms. This additional budgetary revenue will lead, among other things, to a gradual adjustment of income tax and its reduction depending on the target debt levels of individual economies. Furthermore, after 2030 this positive demand shock is be dampened over the subsequent five years by negative sentiment of households and firms, which is shaken by the sudden change in the direction of climate policy. The delays in the implementation of climate policy will result in lower willingness of households to consume and an increase in precautionary savings. The increased uncertainty caused by the rapid introduction of new regulatory measures will also foster an increase in the risk premium and a decline in business investment activity.

The resulting model simulations show that the earlier global climate policy is implemented and enforced, the lower the negative impacts on real economic activity in the world.[8] In the case of physical shocks, there are inevitably higher or lower direct negative impacts of climate change on GDP in all three scenarios (see Chart 3). In addition to the effects that reduce real economic activity, the effects of transition shocks reflecting the implementation of climate policy, which initially further deepens the decline in GDP, are added over a 30-year horizon in the "zero emissions by 2050" and "delayed transition" scenarios. However, in the event of timely implementation of climate policy, as in the case of the "zero emissions by 2050" scenario, the negative effects on GDP can be significantly eliminated assuming that carbon tax revenue is used and partly returned to the economy in the form of government investments. In the event of later implementation of climate policy after 2030 (the "delayed transition" scenario), in addition to the negative impacts reflecting physical shocks, the negative effects of transition shocks are compounded by worsened sentiment of households and firms. Overall, over the next 30 years the negative effects on GDP are highest in this scenario. However, unlike the "current climate policy" scenario, these two scenarios lead to a very significant slowdown in global warming and the negative impacts on the individual world economies after 2050 are low in these scenarios (see Chart 1). Conversely, in the "current climate policy" scenario, the negative impacts of climate change increase markedly over time, leading to irreversible damage to the environment and human health and enormous economic costs after 2050. Delaying the implementation of climate policy will require a stronger response in the future, with the effectiveness of such a response decreasing over time due to rising global temperatures and the damage caused by global warming increasing.

Chart 3 – Impacts on real GDP level in the world

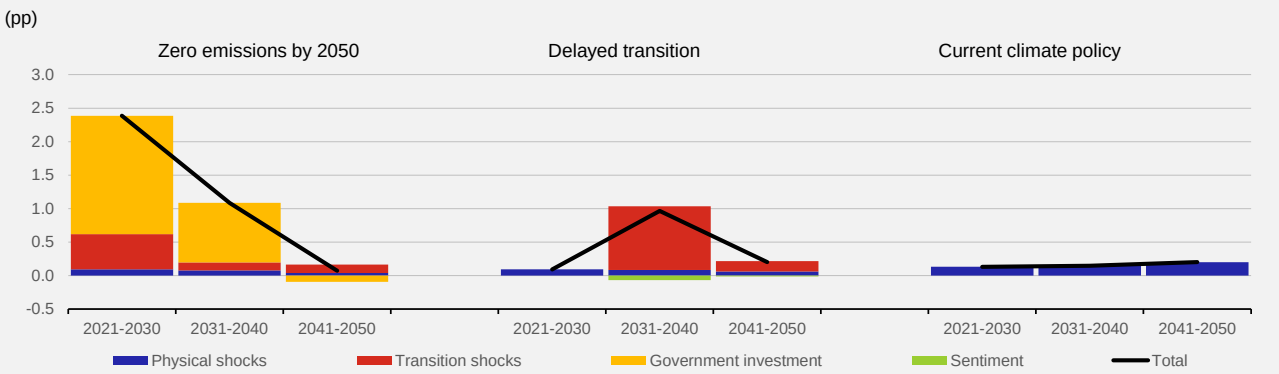


Source: Authors' calculations using the NiGEM model.
Note: Deviations in % from the climate-neutral baseline scenario.

[8] All model projections are calculated against the climate-neutral baseline scenario, which does not include the physical and transition impacts associated with climate change.

Implementing global climate policy will see a temporary faster rise in global prices. This inflationary effect in both the "zero emissions by 2050" and the "delayed transition" scenario mainly reflects the effects of introducing a carbon tax, which are in the transition shock group (see Chart 4). This impact is most evident in the "delayed transition" scenario, where the rise in carbon tax due to delays is initially more pronounced than in the "zero emissions by 2050" scenario (see Chart 2). Overall, however, inflation is at its highest in the "zero emissions by 2050" scenario, reflecting the projected partial inflationary impact of government investment in an effort to support economic growth and mitigate the negative effects of climate change shocks and the implementation of a global climate policy. The slowest price growth by the end of 2050 is implied in the "current climate policy" scenario, which only includes physical shocks but not transition shocks. Physical shocks, however, are the most inflationary in this scenario. These inflationary pressures will strengthen further over time as continued global warming will increasingly distort supply by diminishing the efficiency of the use of production factors in the global economy and anti-inflationary negative demand effects will only partially dampen this price growth. By contrast, in the "zero emissions by 2050" scenario, the inflationary effects associated with physical shocks are only modest, as the inflationary negative supply effects due to the lower productivity of global factors of production are largely dampened by anti-inflationary demand effects. In the "delayed transition" scenario, the slightly inflationary physical shocks are also dampened overall in the short term by the anti-inflationary effects, reflecting the temporary negative sentiment of households and firms following a more forceful implementation of a global climate policy after 2030.

Chart 4 – Impacts on annual consumer price inflation worldwide

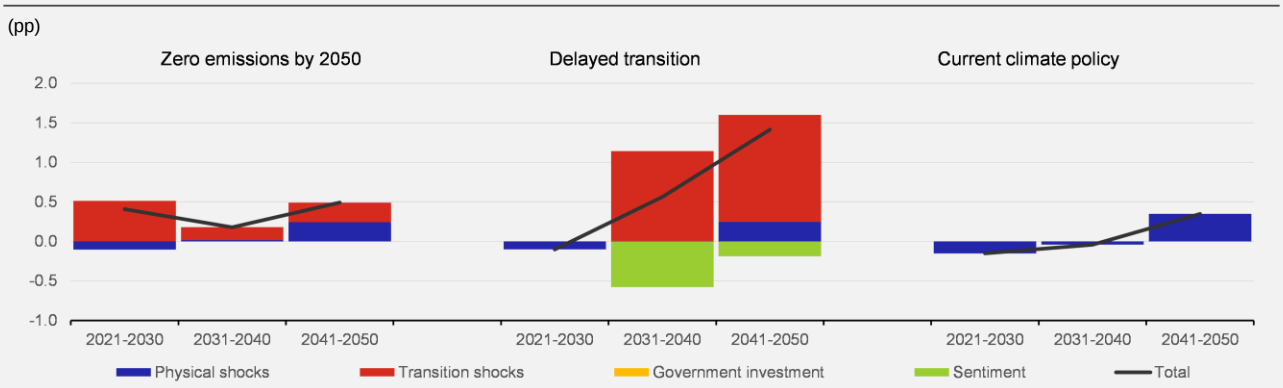


Source: Authors' calculations using the NiGEM model.
Note: Deviations in pp from the climate-neutral baseline scenario.

Overall, the effects of climate change will lead to stagflationary developments and thus to a need for tighter monetary policies of central banks. Charts 5 and 6 describe the monetary policy response using the example of the US Fed and the ECB, showing that the ensuing paths of monetary policy interest rates are broadly the same for the two central banks. Minor deviations are due to the different calibration of climate shocks reflecting the different energy dependence of the two economies.[9] While physical shocks *per se* initially imply interest rate stagnation, or very slightly accommodative monetary policy, interest rates rise over time in all three climate scenarios as inflationary negative supply effects gradually become more prevalent over the anti-inflationary demand ones. This trend is most visible in the "current climate policy" scenario, which will see a further strengthening of the inflationary effects after 2050 on the back of a continued rise in global temperatures and the growing number and scale of devastating natural disasters which will reduce production capacities, requiring faster interest rate increases. Besides the inflationary effects of physical shocks in the "zero emissions by 2050" and "delayed transition" scenarios in the medium term, there are also the obvious inflationary effects of climate policy implementation. These upward pressures on interest rates are most visible in the "delayed transition" scenario, which includes a greater increase in the carbon tax after 2030 and the associated rise in prices of production inputs. By contrast, in the "zero emissions by 2050" scenario, the increase in the carbon tax is more gradual at the start of the forecast horizon and the endogenous monetary policy response no longer contains an additional increase in interest rates corresponding to the inflationary effects of redistributing half of the carbon tax revenue back to the economy through government investment.

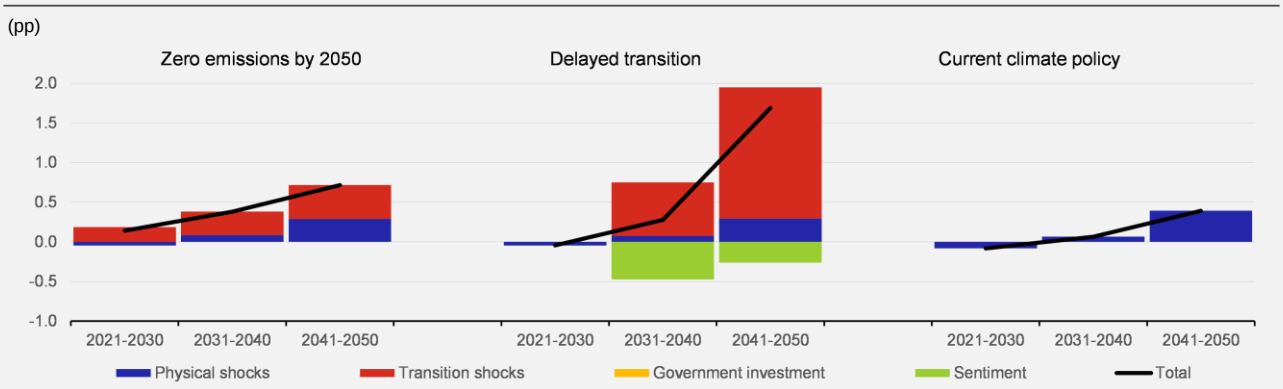
[9] The US economy is a major exporter of fossil energy commodities worldwide, whereas the euro area economy is their importer. Climate policy which puts downward pressure on fossil fuel consumption, the price of which will fall over time, will have stronger negative effects on the US economy. This will also be reflected in a stronger euro against the US dollar.

Chart 5 – Monetary policy response of US central bank (Fed)



Source: Authors' calculations using the NiGEM model.
Note: Deviations in pp from the climate-neutral baseline scenario.

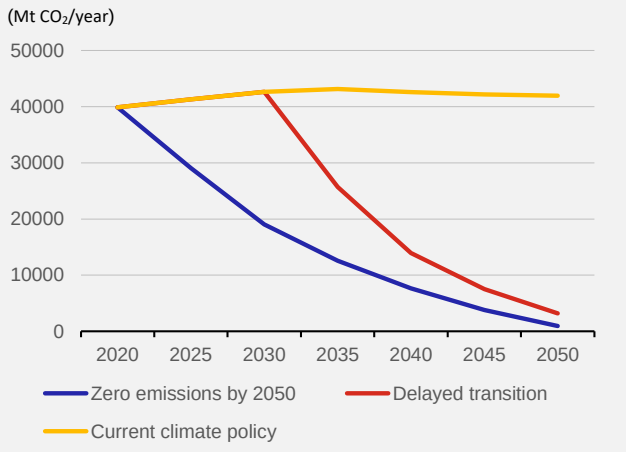
Chart 6 – Monetary policy response of euro area central bank (ECB)



Source: Authors' calculations using the NiGEM model.
Note: Deviations in pp from the climate-neutral baseline scenario.

While the "zero emissions by 2050" and "delayed transition" scenarios assume that the long-term climate target will be achieved by the end of 2050, the "current climate policy" scenario implies irreversible and increasing damage over time. The "zero emissions by 2050" scenario assumes that a carbon-free global economy will be achieved by the end of the forecast horizon (see Chart 7). The "delayed transition" climate scenario also achieves a similar level of reduction in global CO_2 emissions. However, due to a ten-year delay in the implementation of global climate policy compared with the previous scenario, the economic cost of achieving this target is higher. This will come in the form of a significant decline in GDP over the entire forecast horizon amid higher inflation, to which monetary policy will respond with sharp rises in interest rates. By contrast, in the "current climate policy" scenario, CO_2 emissions are reduced only minimally and not until the second half of the forecast horizon. This will be reflected in a continued rapid rate of global warming (see Chart 1), which will lead to huge irreversible damage beyond the forecast horizon.

Chart 7 – Impacts on total global CO_2 emissions



Source: REMIND-MAgPIE global climate model.

Conclusion

Current research suggests a need to reassess and expand central banks' analytical systems to include models capturing the economic impacts of climate change. Climate change and the transition to low carbon emission economies will increasingly influence price stability through its impacts on macroeconomic indicators such as real economic activity, output, employment, interest rates, investment and productivity. We can also expect climate change to affect the area of financial stability and monetary policy. Models including climate change variables may be an example of a possible expansion of the analytical portfolio (see the NiGEM model). Central banks should also carry out financial sector stress tests with both transition shocks and sudden and unexpected physical shocks.

Model simulations show that climate change will have global stagflationary effects overall. This long-term and intensifying partial shock beyond the normal business cycle will foster higher inflation and slower economic growth. This is illustrated by analyses carried out using the NiGEM global model and three hypothetical climate scenarios, i.e. the "zero emissions by 2050", "delayed transition" and "current climate policy" scenarios. The simulations include the direct effects of climate change (physical shocks) which lead overall to a decline in GDP and rising prices, as the inflationary effects resulting from supply disruptions outweigh the anti-inflationary effects reflecting lower demand. On the supply side, global warming and the associated rising frequency and scale of devastating natural disasters will be reflected in a reduction in the production factors of labour and capital, leading to a decline in the potential of individual economies and thus to a reduction in overall global production capacity. The negative demand impacts will be felt in a decline in private consumption and investment. The "zero emissions by 2050" and "delayed transition" simulations include additional risks (transition shocks) which take into account shocks reflecting the impacts of global climate policy, i.e. an increase in carbon tax, a decrease in the energy intensity of production, a decrease in the consumption of fossil energy sources (coal, oil, gas) and an increase in the consumption of renewable energy sources. Overall, these additional factors will also manifest themselves as an inflationary cost shock and a negative supply shock with negative effects on GDP.

Climate change and the associated economic effects bring about a need for tighter monetary policy globally. This conclusion based on model simulations is demonstrated using the example of Fed and ECB monetary policy. While physical shocks imply interest rate stagnation in the short term, or a very slightly accommodative monetary policy, the strengthening inflationary effect of the negative supply-side effects will lead to interest rate growth in all three climate scenarios over the forecast horizon. The clear inflationary effects of global climate policy implementation in the context of transition shocks add to the slight inflationary effects of physical shocks in the "zero emissions by 2050" and "delayed transition" scenarios.

The climate scenarios assume that postponing the implementation of global climate policy will lead not only to higher economic costs, but mainly to irreversible damage to the environment and human health. The results of the analyses show that, in the event of timely implementation of global climate policy (see the "zero emissions by 2050" scenario), a more pronounced decline in real economic activity can be avoided at the cost of higher inflation in the short term. This scenario means a long-term sustainable temperature profile reflecting the transition towards a carbon-free global economy by the end of 2050. A similar level of reduction of CO_2 emissions is achieved in the "delayed transition" scenario, but at higher economic costs. By contrast, the "current climate policy" scenario, which has a minimal impact on reducing CO_2 emissions, would lead to long-term growth in the global temperature profile coupled with huge and lasting damage.

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Keywords

climate change, monetary policy, macroeconomic modelling

JEL Classification

E2, E37, E4, E58, G11, G12, G21, G28, Q43, O44, Q51, Q54

A1. Change in predictions for 2021

GDP growth, %

	CF		IMF		OECD		CB / EIU	
EA	+0.2	2021/9 2021/8	+0.2	2021/7 2021/4	+0.4	2021/5 2021/3	+0.4	2021/9 2021/6
US	-0.3	2021/9 2021/8	+0.6	2021/7 2021/4	+0.4	2021/5 2021/3	+0.5	2021/6 2021/3
UK	-0.1	2021/9 2021/8	+1.7	2021/7 2021/4	+2.1	2021/5 2021/3	0	2021/8 2021/5
JP	-0.1	2021/9 2021/8	-0.5	2021/7 2021/4	-0.1	2021/5 2021/3	-0.2	2021/7 2021/4
CN	-0.2	2021/9 2021/8	-0.3	2021/7 2021/4	+0.7	2021/5 2021/3	0	2021/8 2021/7
RU	+0.3	2021/8 2021/7	+0.6	2021/7 2021/4	+0.8	2021/5 2021/3	+0.1	2021/8 2021/7

Inflation, %

	CF		IMF		OECD		CB / EIU	
EA	+0.1	2021/9 2021/8	+0.5	2021/4 2020/10	+1.1	2021/5 2020/12	+0.3	2021/9 2021/6
US	+0.2	2021/9 2021/8	-0.5	2021/4 2020/10	+1.5	2021/5 2020/12	+1.0	2021/6 2021/3
UK	0	2021/9 2021/8	+0.3	2021/4 2020/10	+0.6	2021/5 2020/12	+1.5	2021/8 2021/5
JP	-0.3	2021/9 2021/8	-0.2	2021/4 2020/10	-0.1	2021/5 2020/12	+0.5	2021/7 2021/4
CN	-0.1	2021/9 2021/8	-1.5	2021/4 2020/10	-0.8	2021/5 2020/12	-0.3	2021/8 2021/7
RU	+0.1	2021/8 2021/7	+1.3	2021/4 2020/10	+1.8	2021/5 2020/12	+0.1	2021/8 2021/7

A2. Change in predictions for 2022

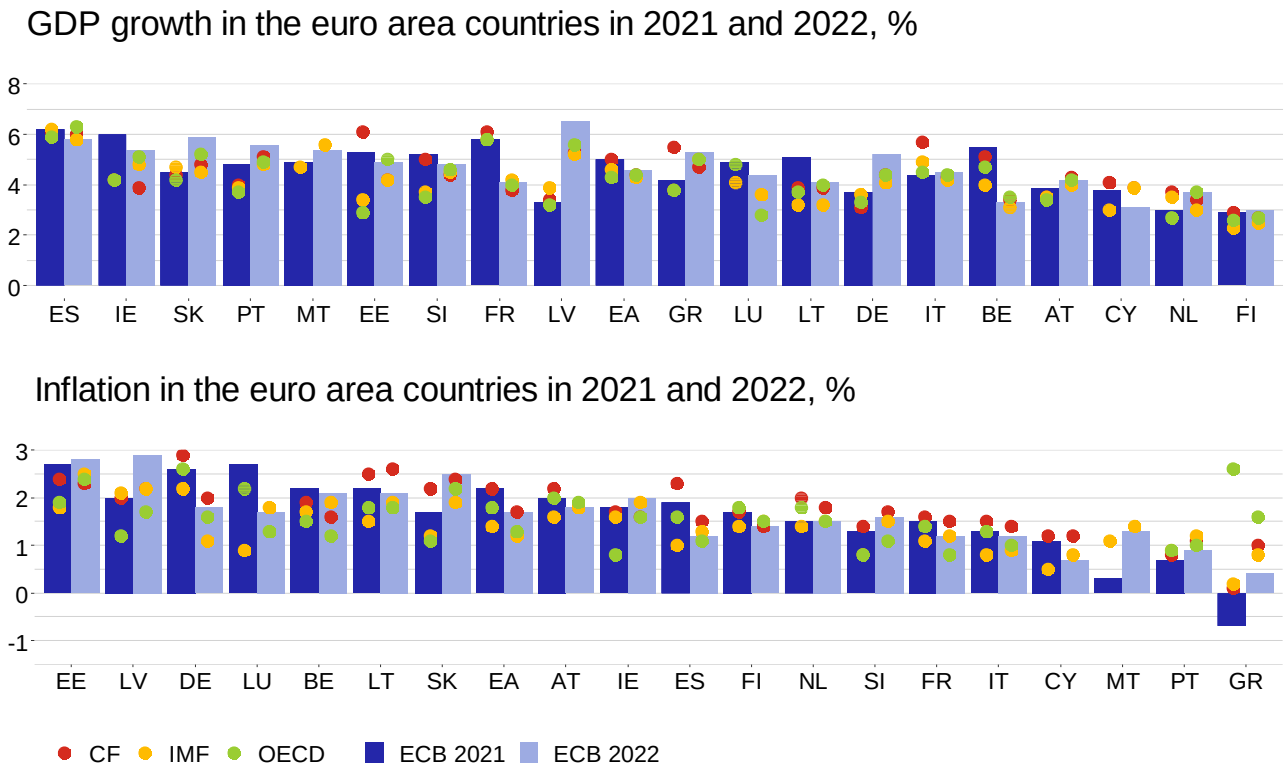
GDP growth, %

	CF		IMF		OECD		CB / EIU	
EA	0	2021/9 2021/8	+0.5	2021/7 2021/4	+0.6	2021/5 2021/3	-0.1	2021/9 2021/6
US	-0.1	2021/9 2021/8	+1.4	2021/7 2021/4	-0.4	2021/5 2021/3	0	2021/6 2021/3
UK	0	2021/9 2021/8	-0.3	2021/7 2021/4	+0.8	2021/5 2021/3	+0.2	2021/8 2021/5
JP	0	2021/9 2021/8	+0.5	2021/7 2021/4	+0.2	2021/5 2021/3	+0.3	2021/7 2021/4
CN	-0.9	2021/9 2021/8	+0.1	2021/7 2021/4	+0.9	2021/5 2021/3	0	2021/8 2021/7
RU	+0.1	2021/8 2021/7	-0.7	2021/7 2021/4	+0.2	2021/5 2021/3	+0.2	2021/8 2021/7

Inflation, %

	CF		IMF		OECD		CB / EIU	
EA	+0.2	2021/9 2021/8	0	2021/4 2020/10	+0.3	2021/5 2020/12	+0.2	2021/9 2021/6
US	+0.2	2021/9 2021/8	+0.3	2021/4 2020/10	+1.0	2021/5 2020/12	+0.1	2021/6 2021/3
UK	+0.1	2021/9 2021/8	+0.2	2021/4 2020/10	+0.2	2021/5 2020/12	+0.5	2021/8 2021/5
JP	0	2021/9 2021/8	0	2021/4 2020/10	+0.2	2021/5 2020/12	+0.1	2021/7 2021/4
CN	-0.1	2021/9 2021/8	-0.7	2021/4 2020/10	+0.3	2021/5 2020/12	0	2021/8 2021/7
RU	-0.1	2021/8 2021/7	+0.2	2021/4 2020/10	+0.4	2021/5 2020/12	+0.5	2021/8 2021/7

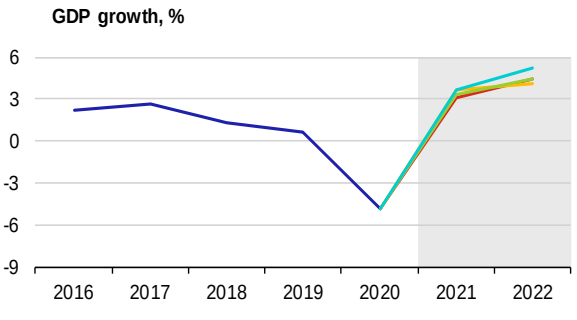
A3. GDP growth and inflation outlooks in the euro area countries



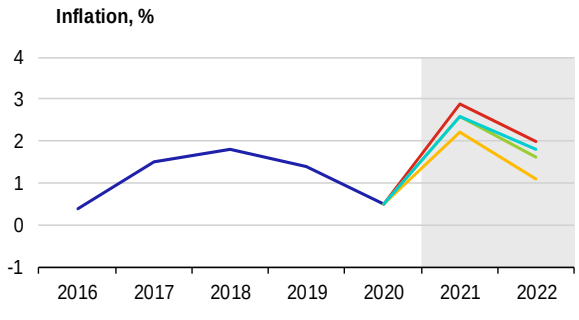
Note: Charts show institutions' latest available outlooks of for the given country.

A4. GDP growth and inflation in the individual euro area countries

Germany



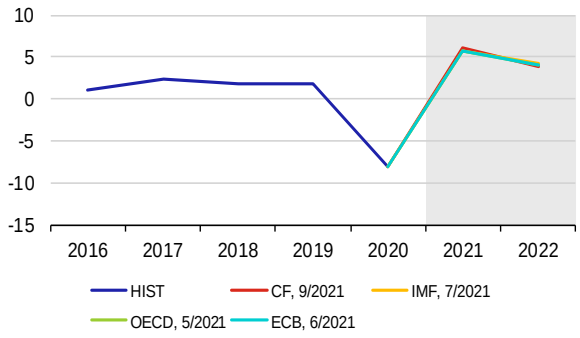
	CF	IMF	OECD	DBB
2021	3.1	3.6	3.3	3.7
2022	4.4	4.1	4.4	5.2



	CF	IMF	OECD	DBB
2021	2.9	2.2	2.6	2.6
2022	2.0	1.1	1.6	1.8

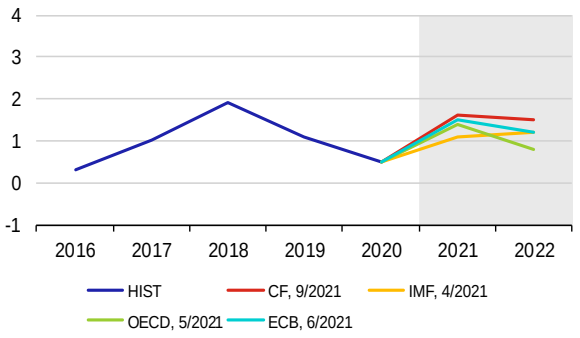
France

GDP growth, %



	CF	IMF	OECD	ECB
2021	6.1	5.8	5.8	5.8
2022	3.8	4.2	4.0	4.1

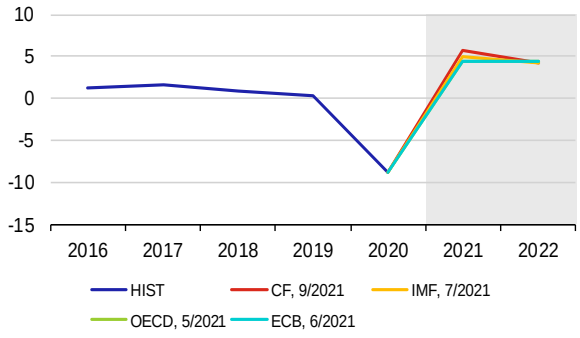
Inflation, %



	CF	IMF	OECD	ECB
2021	1.6	1.1	1.4	1.5
2022	1.5	1.2	0.8	1.2

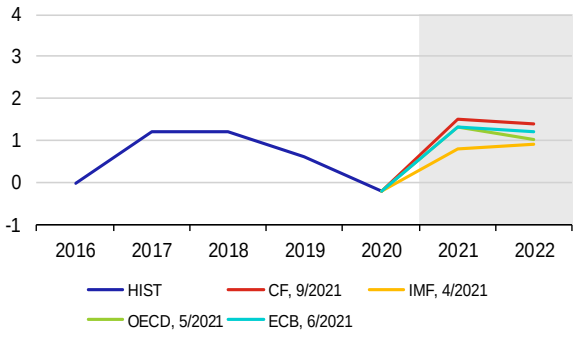
Italy

GDP growth, %



	CF	IMF	OECD	ECB
2021	5.7	4.9	4.5	4.4
2022	4.3	4.2	4.4	4.5

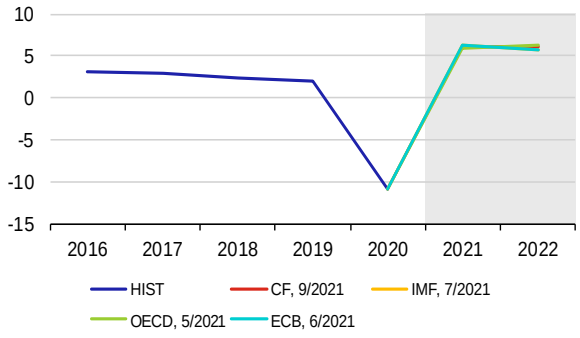
Inflation, %



	CF	IMF	OECD	ECB
2021	1.5	0.8	1.3	1.3
2022	1.4	0.9	1.0	1.2

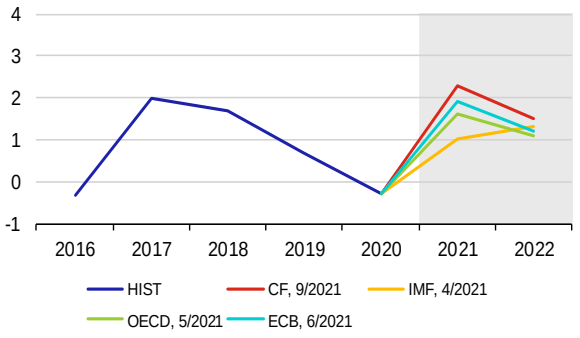
Spain

GDP growth, %



	CF	IMF	OECD	ECB
2021	6.1	6.2	5.9	6.2
2022	6.0	5.8	6.3	5.8

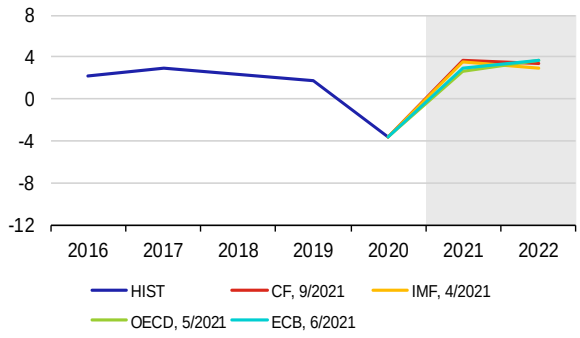
Inflation, %



	CF	IMF	OECD	ECB
2021	2.3	1.0	1.6	1.9
2022	1.5	1.3	1.1	1.2

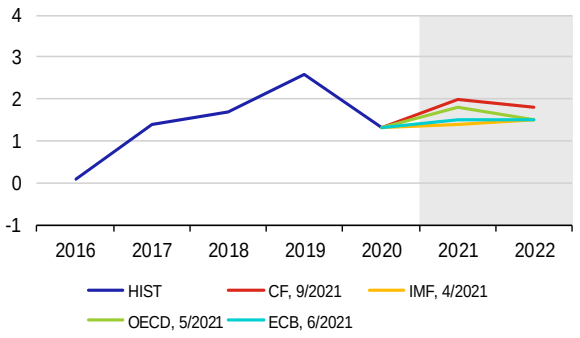
Netherlands

GDP growth, %



	CF	IMF	OECD	ECB
2021	3.7	3.5	2.7	3.0
2022	3.4	3.0	3.7	3.7

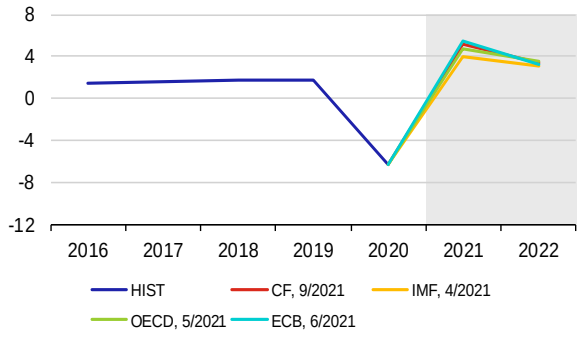
Inflation, %



	CF	IMF	OECD	ECB
2021	2.0	1.4	1.8	1.5
2022	1.8	1.5	1.5	1.5

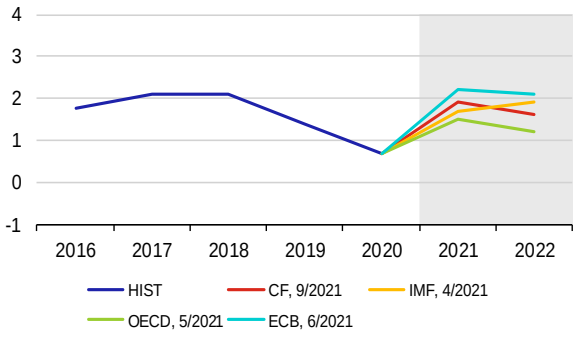
Belgium

GDP growth, %



	CF	IMF	OECD	ECB
2021	5.1	4.0	4.7	5.5
2022	3.4	3.1	3.5	3.3

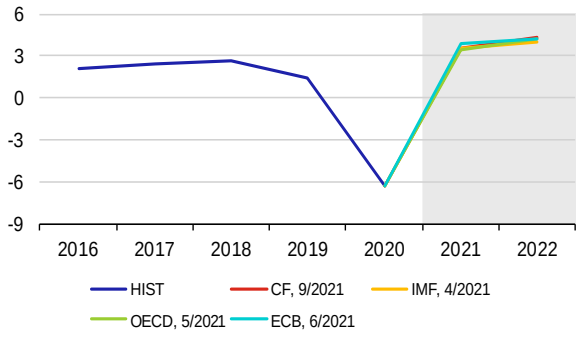
Inflation, %



	CF	IMF	OECD	ECB
2021	1.9	1.7	1.5	2.2
2022	1.6	1.9	1.2	2.1

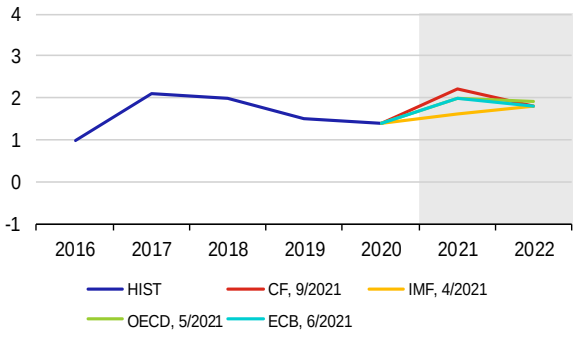
Austria

GDP growth, %



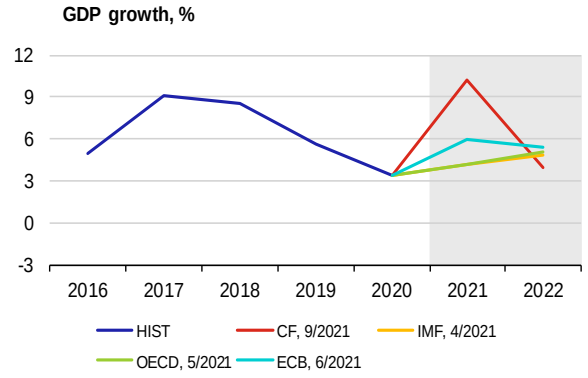
	CF	IMF	OECD	ECB
2021	3.5	3.5	3.4	3.9
2022	4.3	4.0	4.2	4.2

Inflation, %

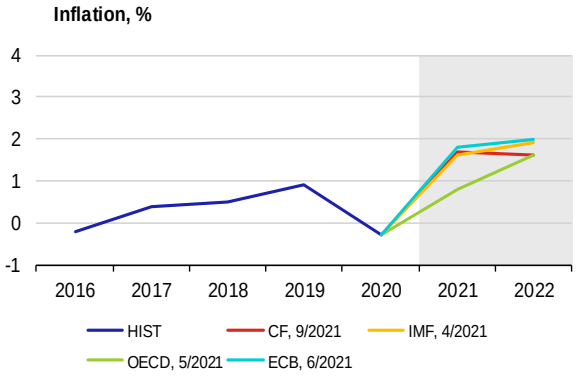


	CF	IMF	OECD	ECB
2021	2.2	1.6	2.0	2.0
2022	1.8	1.8	1.9	1.8

Ireland

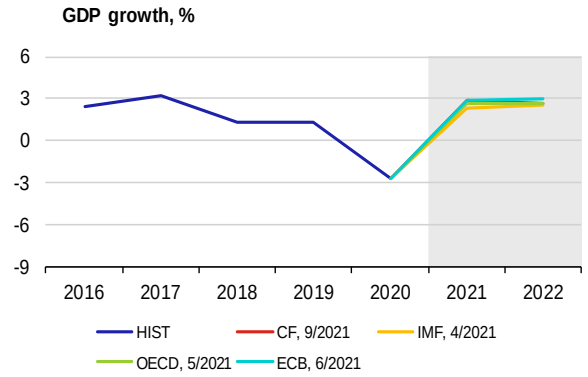


	CF	IMF	OECD	ECB
2021	10.2	4.2	4.2	6.0
2022	3.9	4.8	5.1	5.4

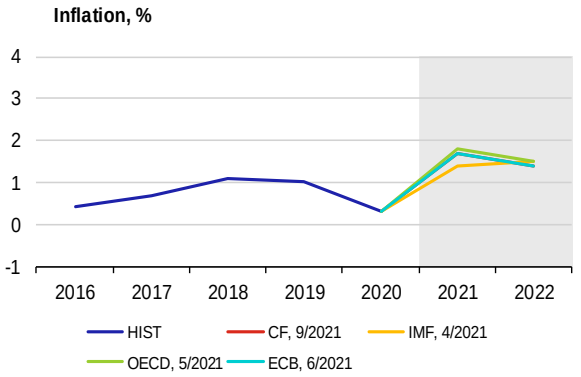


	CF	IMF	OECD	ECB
2021	1.7	1.6	0.8	1.8
2022	1.6	1.9	1.6	2.0

Finland

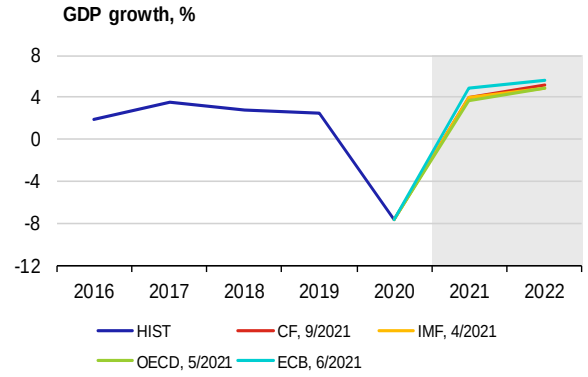


	CF	IMF	OECD	ECB
2021	2.9	2.3	2.6	2.9
2022	2.7	2.5	2.7	3.0

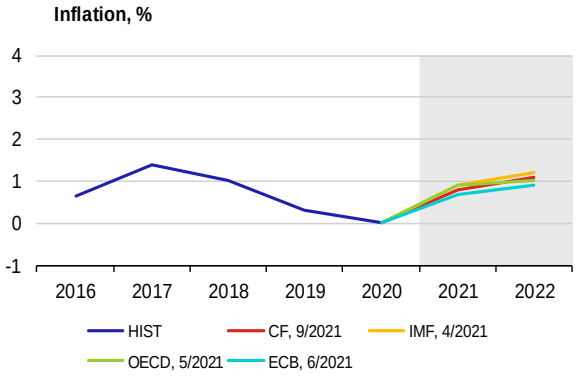


	CF	IMF	OECD	ECB
2021	1.7	1.4	1.8	1.7
2022	1.4	1.5	1.5	1.4

Portugal

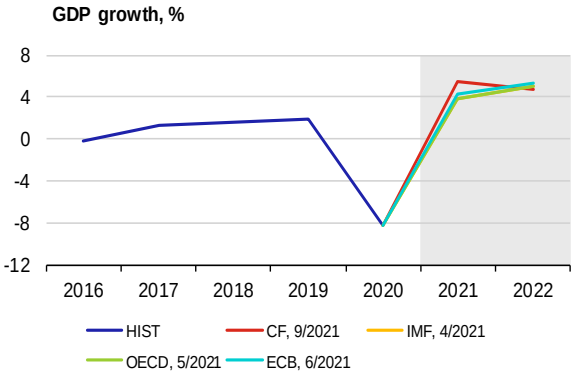


	CF	IMF	OECD	ECB
2021	4.0	3.9	3.7	4.8
2022	5.1	4.8	4.9	5.6

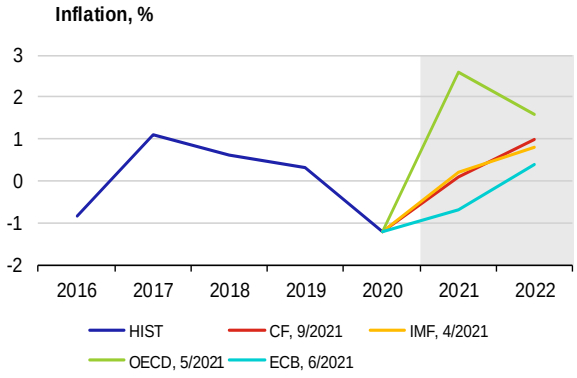


	CF	IMF	OECD	ECB
2021	0.8	0.9	0.9	0.7
2022	1.1	1.2	1.0	0.9

Greece

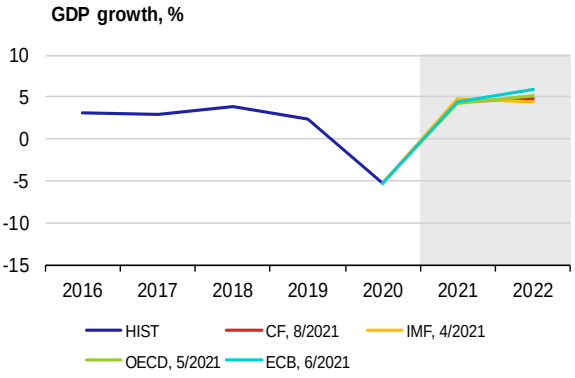


	CF	IMF	OECD	ECB
2021	5.5	3.8	3.8	4.2
2022	4.7	5.0	5.0	5.3

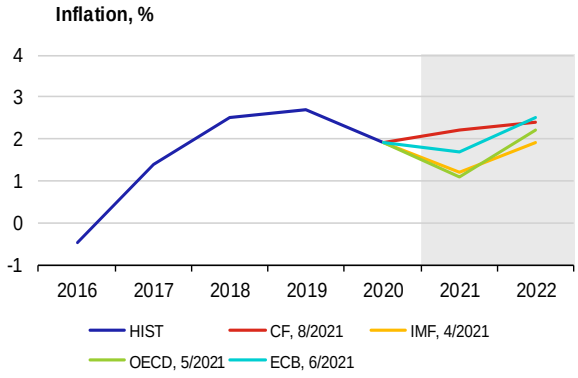


	CF	IMF	OECD	ECB
2021	0.1	0.2	2.6	-0.7
2022	1.0	0.8	1.6	0.4

Slovakia

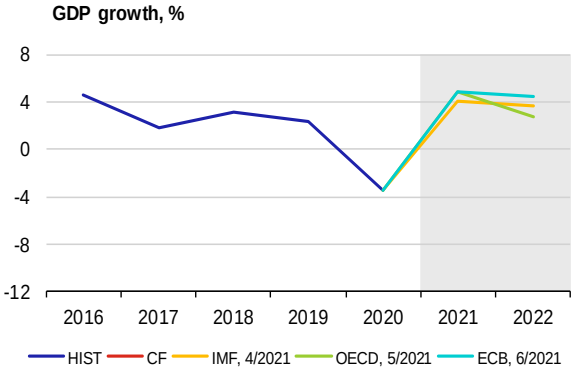


	CF	IMF	OECD	ECB
2021	4.4	4.7	4.2	4.5
2022	4.8	4.5	5.2	5.9

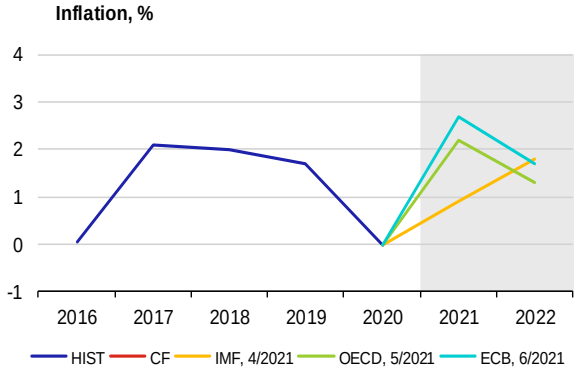


	CF	IMF	OECD	ECB
2021	2.2	1.2	1.1	1.7
2022	2.4	1.9	2.2	2.5

Luxembourg

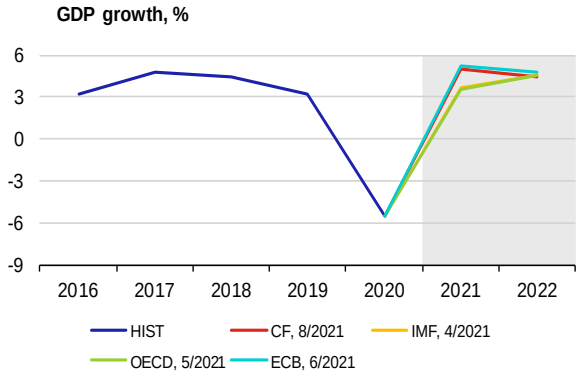


	CF	IMF	OECD	ECB
2021	n. a.	4.1	4.8	4.9
2022	n. a.	3.6	2.8	4.4

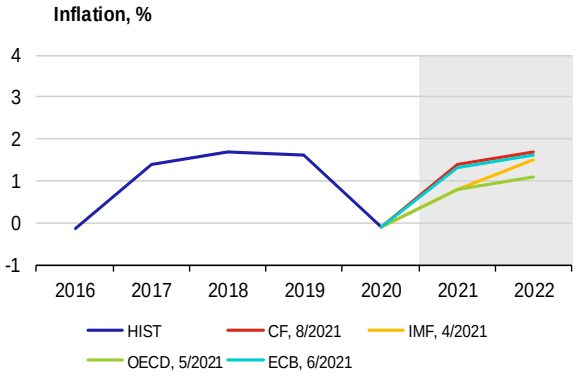


	CF	IMF	OECD	ECB
2021	n. a.	0.9	2.2	2.7
2022	n. a.	1.8	1.3	1.7

Slovenia

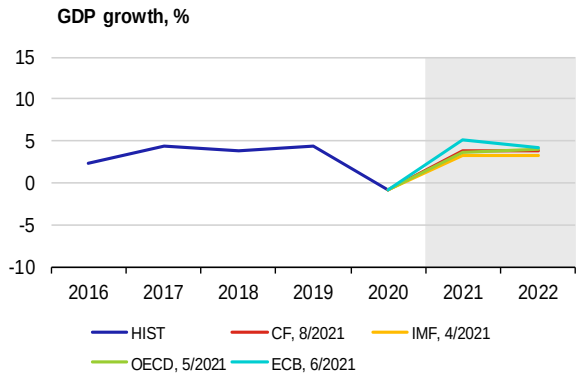


	CF	IMF	OECD	ECB
2021	5.0	3.7	3.5	5.2
2022	4.4	4.5	4.6	4.8

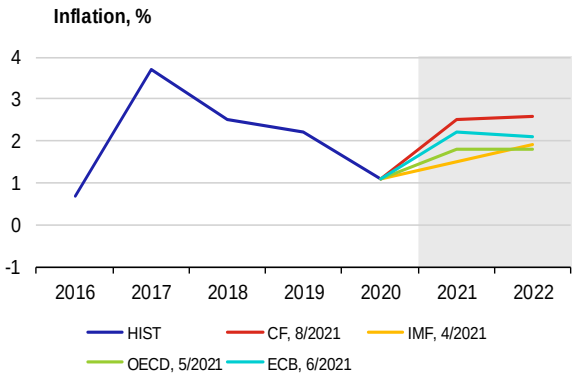


	CF	IMF	OECD	ECB
2021	1.4	0.8	0.8	1.3
2022	1.7	1.5	1.1	1.6

Lithuania

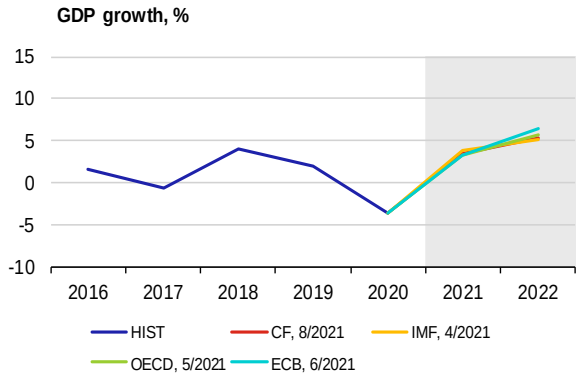


	CF	IMF	OECD	ECB
2021	3.9	3.2	3.7	5.1
2022	3.9	3.2	4.0	4.1

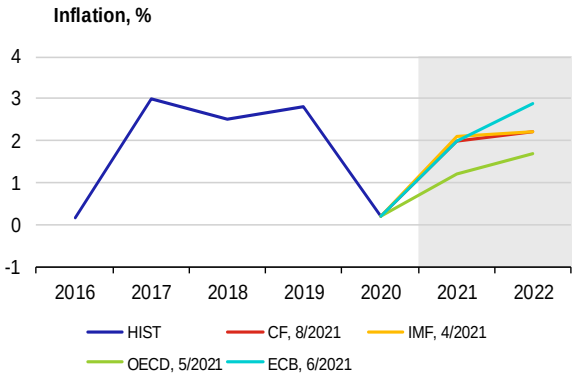


	CF	IMF	OECD	ECB
2021	2.5	1.5	1.8	2.2
2022	2.6	1.9	1.8	2.1

Latvia

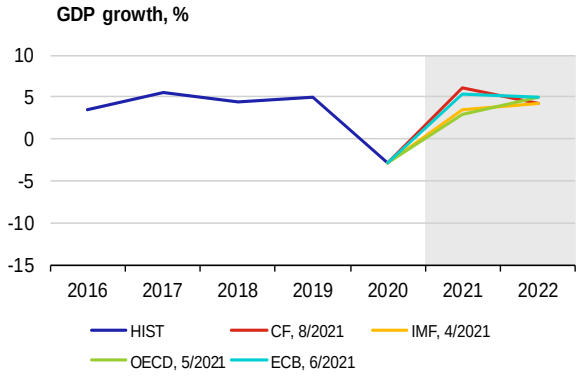


	CF	IMF	OECD	ECB
2021	3.4	3.9	3.2	3.3
2022	5.3	5.2	5.6	6.5

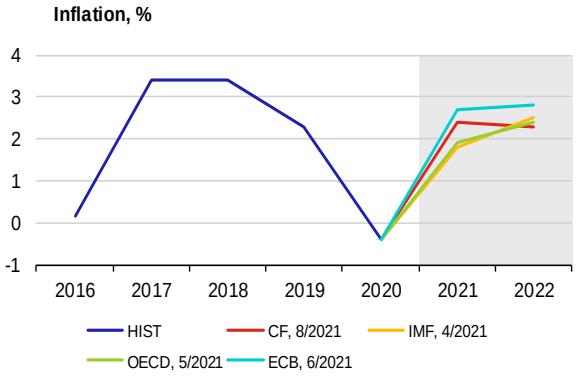


	CF	IMF	OECD	ECB
2021	2.0	2.1	1.2	2.0
2022	2.2	2.2	1.7	2.9

Estonia

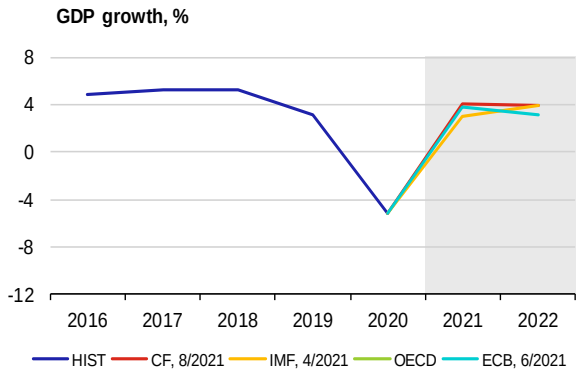


	CF	IMF	OECD	ECB
2021	6.1	3.4	2.9	5.3
2022	4.2	4.2	5.0	4.9

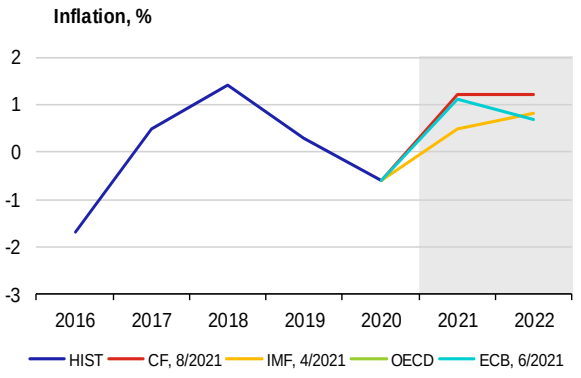


	CF	IMF	OECD	ECB
2021	2.4	1.8	1.9	2.7
2022	2.3	2.5	2.4	2.8

Cyprus

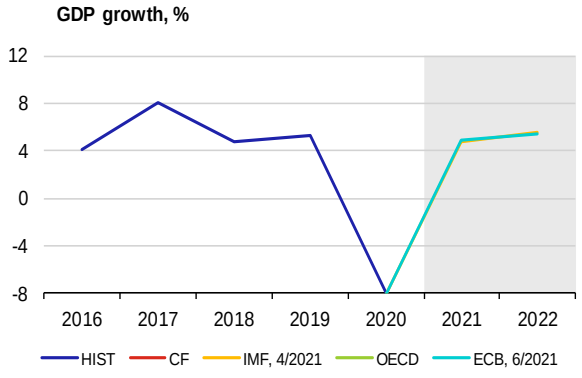


	CF	IMF	OECD	ECB
2021	4.1	3.0	n. a.	3.8
2022	3.9	3.9	n. a.	3.1

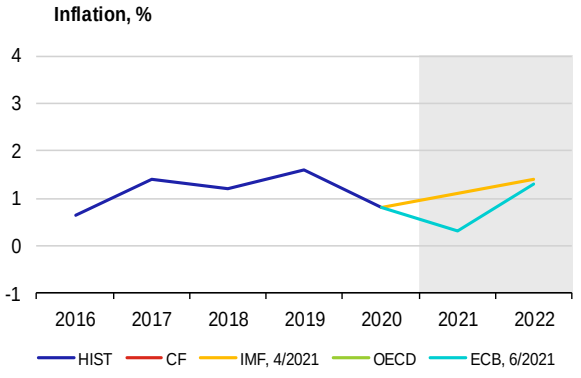


	CF	IMF	OECD	ECB
2021	1.2	0.5	n. a.	1.1
2022	1.2	0.8	n. a.	0.7

Malta



	CF	IMF	OECD	ECB
2021	n. a.	4.7	n. a.	4.9
2022	n. a.	5.6	n. a.	5.4

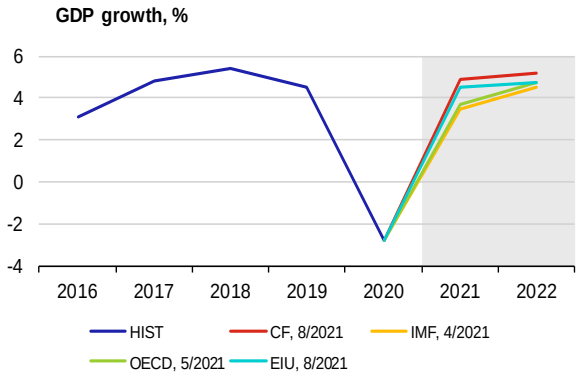


	CF	IMF	OECD	ECB
2021	n. a.	1.1	n. a.	0.3
2022	n. a.	1.4	n. a.	1.3

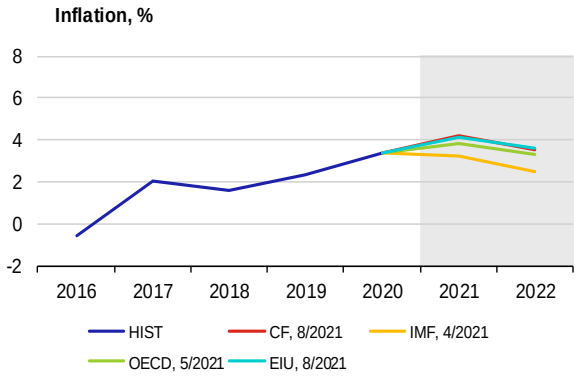
Ddd

A5. GDP growth and inflation in other selected countries

Poland

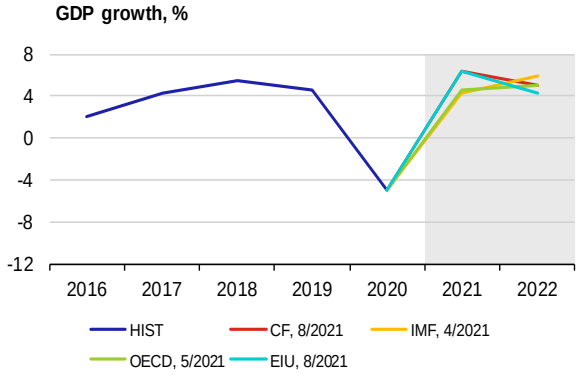


	CF	IMF	OECD	EIU
2021	4.9	3.5	3.7	4.5
2022	5.2	4.5	4.7	4.7

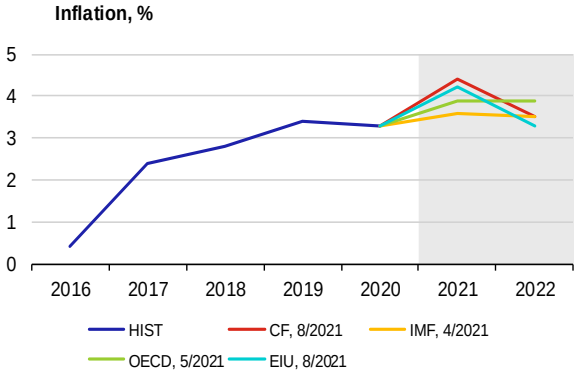


	CF	IMF	OECD	EIU
2021	4.2	3.2	3.8	4.1
2022	3.5	2.5	3.3	3.6

Hungary

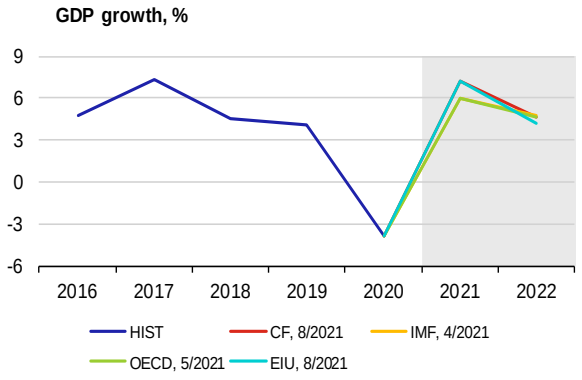


	CF	IMF	OECD	EIU
2021	6.4	4.3	4.6	6.3
2022	5.0	5.9	5.0	4.2

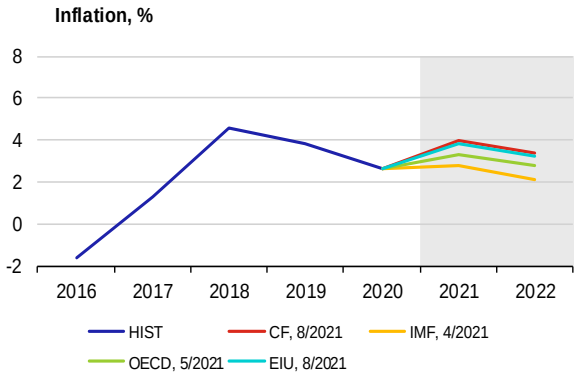


	CF	IMF	OECD	EIU
2021	4.4	3.6	3.9	4.2
2022	3.5	3.5	3.9	3.3

Romania



	CF	IMF	OECD	EIU
2021	7.2	6.0	6.0	7.2
2022	4.6	4.8	4.6	4.2



	CF	IMF	OECD	EIU
2021	4.0	2.8	3.3	3.8
2022	3.4	2.1	2.8	3.2

A6. List of abbreviations

AT	Austria
bbl	barrel
BE	Belgium
BoE	Bank of England (the UK central bank)
BoJ	Bank of Japan (the central bank of Japan)
bp	basis point (one hundredth of a percentage point)
CB	central bank
CBR	Central Bank of Russia
CF	Consensus Forecasts
CN	China
CNB	Czech National Bank
CNY	Chinese renminbi
ConfB	Conference Board Consumer Confidence Index
CXN	Caixin
CY	Cyprus
DBB	Deutsche Bundesbank (the central bank of Germany)
DE	Germany
EA	euro area
ECB	European Central Bank
EE	Estonia
EIA	Energy Information Administration
EIU	Economist Intelligence Unit
ES	Spain
ESI	Economic Sentiment Indicator of the European Commission
EU	European Union
EUR	euro
EURIBOR	Euro Interbank Offered Rate
Fed	Federal Reserve System (the US central bank)
FI	Finland
FOMC	Federal Open Market Committee
FR	France
FRA	forward rate agreement
FY	fiscal year
GBP	pound sterling
GDP	gross domestic product
GR	Greece
ICE	Intercontinental Exchange
IE	Ireland
IEA	International Energy Agency
IFO	Leibniz Institute for Economic Research at the University of Munich
IMF	International Monetary Fund
IRS	Interest Rate swap
ISM	Institute for Supply Management
IT	Italy
JP	Japan
JPY	Japanese yen
LIBOR	London Interbank Offered Rate
LME	London Metal Exchange
LT	Lithuania
LU	Luxembourg
LV	Latvia
MKT	Markit
MT	Malta
NIESR	National Institute of Economic and Social Research (UK)
NKI	Nikkei
NL	Netherlands
OECD	Organisation for Economic Co-operation and Development
OECD-CLI	OECD Composite Leading Indicator
OPEC+	member countries of OPEC oil cartel and 10 other oil-exporting countries (the most important of which are Russia, Mexico and Kazakhstan)
PMI	Purchasing Managers' Index
pp	percentage point
PT	Portugal
QE	quantitative easing
RU	Russia
RUB	Russian rouble
SI	Slovenia
SK	Slovakia
UK	United Kingdom
UoM	University of Michigan Consumer Sentiment Index - present situation
US	United States
USD	US dollar
USDA	United States Department of Agriculture
WEO	World Economic Outlook
WTI	West Texas Intermediate (crude oil used as a benchmark in oil pricing)
ZEW	Centre for European Economic Research

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