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1 Introduction

The Banco de Portugal projects that the Portuguese economy will grow by 4.8% in 2021, edging nearer to pre-pandemic levels by the end of the year (Table I.1.1). After a quarter-on--quarter decline in the first quarter, GDP more than recovered in the second quarter, continuing to grow throughout the rest of the year, albeit at a slower pace. This recovery path reflects the control of the pandemic and advances in the vaccination process, with positive effects on agents' confidence. Inflation will increase to 0.9% in 2021 (-0.1% in 2020).

Table I.1.1 • Projections of Banco de Portugal for 2021 | Annual rate of change, in percentage (unless otherwise stated)

	Weights 2020	EB October 2021			EB June 2021			EB October 2021 *Memo:* Index 2019 Q4 = 100		
		2019	2020	2021(p)	2019	2020	2021(p)	2019 Q4	2021 Q2	2021 Q4(p)
Gross domestic product (GDP)	100.0	2.7	-8.4	4.8	2.5	-7.6	4.8	100	94.2	98.7
Private consumption	64.2	3.3	-7.1	4.3	2.6	-5.9	3.3	100	97.1	99.0
Public consumption	19.1	2.1	0.4	5.2	0.7	0.4	4.9	100	104.0	107.0
Gross fixed capital formation	19.1	5.4	-2.7	5.6	5.4	-1.9	7.6	100	101.8	104.1
Domestic demand	102.1	3.1	-5.6	4.9	2.8	-4.6	4.5	100	99.2	101.5
Exports	37.0	4.1	-18.6	9.6	3.9	-18.6	14.5	100	81.9	93.6
Exports of goods	26.1	3.3	-7.7	10.7	2.9	-7.6	17.4	100	96.5	100.8
Exports of services	10.9	5.4	-37.2	7.0	5.7	-37.1	7.5	100	57.0	81.3
Imports	39.1	4.9	-12.1	9.7	4.7	-12.0	13.2	100	93.1	99.9
Contribution to GDP growth, net of imports (in p.p.)(a)										
Domestic demand		1.9	-3.0	3.0	1.6	-2.3	2.4			
Exports		0.8	-5.5	1.8	0.9	-5.2	2.5			
Employment (number of persons)(b)		0.8	-1.9	2.6	0.8	-1.7	1.3	100	100.4	102.1
Employment (hours worked)(b)		1.2	-9.3	8.4	1.2	-9.2	5.9	100	98.1	101.8
Unemployment rate(c)		6.6	7.0	6.8	6.6	7.0	7.2			
Current plus capital account (% of GDP)		1.3	0.0	1.0	1.2	0.1	0.9			
Trade balance (% of GDP)		0.8	-1.8	-2.3	0.7	-1.8	-2.1			
Harmonised index of consumer prices		0.3	-0.1	0.9	0.3	-0.1	0.7			
Energy goods		-1.7	-5.2	6.9	-1.7	-5.2	5.6			
Excluding energy goods		0.5	0.3	0.4	0.5	0.3	0.3			

Sources: Banco de Portugal and Statistics Portugal. | Notes: (p) – projected, p.p. – percentage points. The cut-off date for macroeconomic projections is 24 September. (a) The demand aggregates net of imports are obtained by subtracting an estimate of the imports used in each component. For more information on the methodology underlying this calculation, see Cardoso and Rua (2021) "Unveiling the real contribution of final demand to GDP growth", Banco de Portugal, *Economic Studies* – Vol. 7, No. 3. (b) According to the national accounts concept. (c) In percentage of labour force.

Policy measures will continue to support the economy's productive capacity and household and corporate income. In the first half of the year, fiscal policy remained expansionary in the pandemic context (Box 1). In the second half, despite the end of some temporary support – partly replaced by measures more targeted at the most affected sectors and enterprises –, no significant adverse effects on activity are expected.

The projection for GDP in 2021 remains unchanged from that released in June. On the one hand, the incorporation of the revised National Accounts resulted in a stronger recovery in

activity in the second half of 2020, with a positive impact on the annual rate of change in 2021. The GDP growth (quarter-on-quarter) in the second quarter of this year was also slightly higher than that anticipated in June as a result of stronger growth in private consumption. On the other hand, in the second half of 2021, a greater slowdown in private consumption and a worsening of global supply disruptions – with a negative impact on investment and goods exports – result in a downward revision of GDP growth. The projection for inflation in 2021 was revised upwards (by 0.2 p.p.), reflecting an increase in external price pressures compared with June projections.

2 External environment, financing conditions and policies

The international environment remains favourable despite problems in the supply chains of goods. In 2021, global activity and trade will grow by 6.1% and 11.2% respectively, standing more than 4% above the pre-pandemic level at the end of the year (Table I.2.1). External demand for Portuguese goods and services will rise by 9.1% (-11.4% in 2020), slightly above the assumptions in the June *Economic Bulletin*. The speed and synchronicity of the recovery in global demand for goods created disruptions in supplies, as evidenced by a scarcity of commodities and intermediate goods, longer delivery times and high transport costs (Chart I.2.1). These problems have constrained the production of various goods, such as cars, and they are not expected to dissipate until the end of the year.

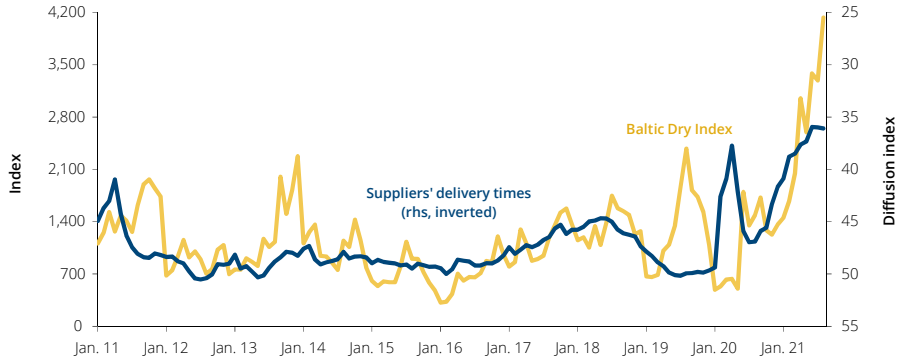
Table I.2.1 • Projection assumptions

		EB October 2021			EB June 2021		
		2019	2020	2021	2019	2020	2021
International environment							
World GDP	yoy	2.7	-2.8	6.1	2.7	-2.9	6.0
World trade	yoy	1.0	-8.5	11.2	0.8	-8.7	10.0
External demand	yoy	2.0	-11.4	9.1	1.9	-11.5	8.6
Oil prices in dollars	aav	64.0	42.3	67.8	64.0	42.3	65.8
Oil prices in euros	aav	57.2	37.1	56.9	57.2	37.1	54.5
Monetary and financial conditions							
Short-term interest rate (3-month EURIBOR)	%	-0.4	-0.4	-0.5	-0.4	-0.4	-0.5
Implicit interest rate in public debt	%	2.6	2.2	2.0	2.6	2.2	2.0
Effective exchange rate index	yoy	-1.5	3.3	1.5	-1.5	3.3	2.3
Euro-dollar exchange rate	aav	1.12	1.14	1.19	1.12	1.14	1.21

Source: Eurosystem (Banco de Portugal calculations). | Notes: yoy – year-on-year rate of change, % – per cent, aav – annual average value. Technical and external environment assumptions, as well as projections for euro area GDP and inflation, coincide with those in the ECB's projection exercise released on 9 September (see "ECB staff macroeconomic projections for the euro area", September 2021). Technical assumptions include information available up to 16 August. The technical assumption for oil prices is based on futures markets. Developments in the 3-month Euribor rate are based on expectations implied in futures contracts. The implicit interest rate on public debt is computed as the ratio of interest expenditure for the year to the simple average of the stock of debt at the end of the same year and at the end of the preceding year. The implicit rate includes an assumption for the interest rate associated with new issuances. An increase in the exchange rate corresponds to an appreciation. The effective exchange rate of the euro is computed against 42 trading partner countries. The technical assumption for bilateral exchange rates assumes that the average levels observed in the two weeks prior to the cut-off date will remain stable over the projection horizon.

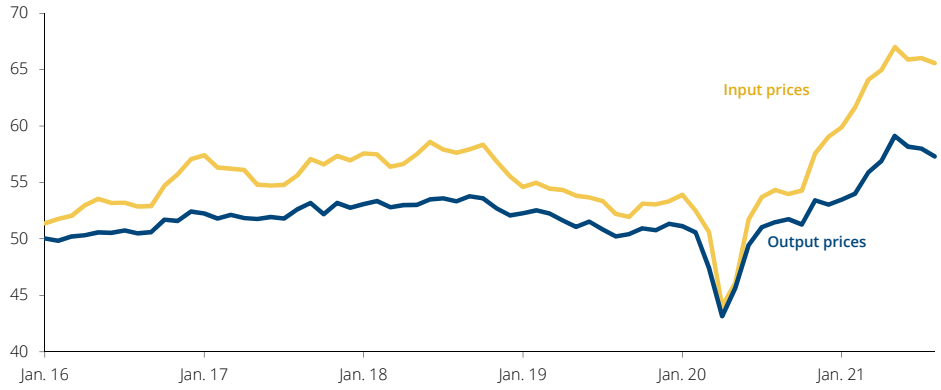
Commodity prices will increase markedly in 2021, after the low levels observed in the previous year. Following an increase of around 50% between the end of 2020 and the end of the first half of 2021, oil prices are expected to stabilise at around €60 per barrel in the second half of the year, close to the level observed in 2019 (Table I.2.1). These assumptions were revised upwards due to the more significant increase in oil prices in US dollars and the depreciation of the euro against the US dollar. Assumptions also point to a sharp rise in non-energy commodity prices in euro in 2021 (31.8%, from 1.3% in the previous year). These increases have had an impact on global input and output prices (Chart I.2.2).

Chart I.2.1 • Maritime transport costs and suppliers' delivery times



Sources: Baltic Exchange and IHS Markit. | Notes: The Baltic Dry Index provides a benchmark for the price of moving the major raw materials by sea (dry bulk), taking into account more than 20 different shipping routes carrying coal, iron ore, grains and various other commodities. Suppliers' delivery times – global manufacturing PMI; readings below 50 indicate that delivery times have deteriorated. The latest observations refer to the month of August 2021.

Chart I.2.2 • Global input and output prices | Diffusion index



Source: IHS Markit. | Notes: Input and output prices – global composite PMI (industry and services); readings above 50 indicate that prices have increased. The latest observations refer to the month of August 2021.

Inflation will increase in the main advanced economies in 2021. For the euro area, the ECB projects inflation to average 2.2% in 2021 (0.3% in 2020), reflecting, in addition to the rise in commodity prices, other factors such as the end of the temporary reduction in VAT in Germany and the increase in services prices, with the lifting of health restrictions. The OECD also anticipates a rise in inflation in the United States and in the United Kingdom. However, in the assessment of the main central banks, the rise in inflation is expected to be temporary, dissipating with the

gradual normalisation of supply chains, in a context where longer-term inflation expectations remain consistent with price stability. In the euro area, the ECB adopted a symmetric inflation objective of 2% over the medium term as part of the monetary policy strategy review finalised in early July (Special issue I).

In the major advanced economies, fiscal policy enhanced support to economic activity. According to the IMF, the cumulative fiscal impact of discretionary measures implemented or announced in response to the pandemic crisis in advanced economies up to June 2021 stood at 17.3% of GDP. At the end of June, the European Commission raised €35 billion in the first two bond issuances related to the Next Generation EU (NGEU), while making the first disbursments under the REACT-EU amounting to €800 million.

Financing conditions will remain favourable in 2021, benefiting from the ECB's accommodative monetary policy. The ECB's balance sheet as a percentage of GDP increased by 5.7 p.p. in the first half of the year, standing at 67.5% of the euro area's GDP. From March 2021 onwards, the ECB significantly increased the pace of monthly purchases under the Pandemic Emergency Purchase Programme (PEPP) in order to preserve favourable financing conditions in the euro area, although the total envelope of the programme remained unchanged. At the same time, targeted longer-term refinancing operations contributed to incentivising bank lending in the euro area. These favourable financing conditions were passed on to the Portuguese economy. Portuguese banks increased central bank funding in the first half of the year and continued financing the private sector at historically low interest rates.

In Portugal, lending to firms continued to expand, notably lending to smaller firms and firms in the accommodation and food and industry sectors (Table I.2.2). The annual rate of change in bank lending to firms stood at 10% in March, decelerating to 6.3% in June. Underlying this deceleration is the reduction of new State-guaranteed loans (from 40% to 20% of total new loans with maturities of over one year). Nevertheless, loans maintained robust growth, to which contributed the decrease in repayments, partly associated with moratoria. As a result of the support measures, the typical corporate loan increased in the pandemic crisis, although it had declined in the sovereign debt crisis (Box 2). In tandem with credit developments, deposits increased in the first half of the year (annual rate of change of 14.6%), representing a liquidity buffer for firms.

New loans to households also continued to grow, especially lending for house purchase that reached 2008 levels, amid buoyant real estate prices. The increase in new loans for house purchase was higher than the change in the value of housing transactions, resulting in a higher share financed by loans (46% in the first half of the year, compared with a 41% average in the five years prior to the pandemic crisis). In line with developments in private consumption, new loans for consumption and other purposes fell in the first quarter but recovered in the second quarter. The share of private consumption (excluding food) financed by loans stood at 4.6% in the first half of the year (5.2% in the five years prior to the pandemic crisis).

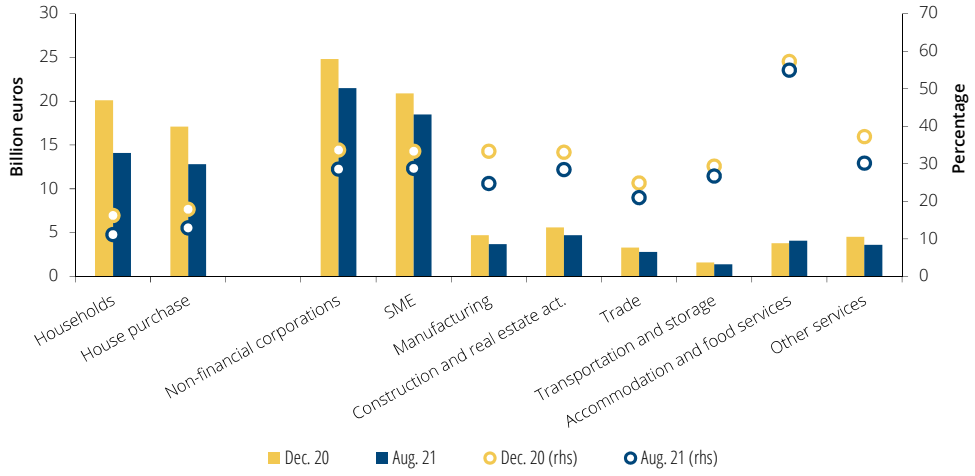
The share of loans under moratoria decreased in the course of 2021. In August, 11.1% of the amount of loans to households were covered by a moratorium, 5.1 p.p. less than in 2020. This corresponds to a 29.7% decrease in the total amount of loans to households under moratoria compared with December 2020 (-25.2% in the housing segment). For non-financial corporations, 28.5% of the amount of loans benefited from a credit moratorium in August, 5.1 p.p. less than at the end of 2020 (Chart I.2.3). This corresponds to a 13.2% decrease in the total value of loans under moratoria compared with December 2020, standing out the decline in manufacturing and other services sectors (-20.1% and -19.4% respectively) and the constrasting increase in the accommodation and food services sector (9.3%).

Table I.2.2 • Interest rates and annual rate of change of bank loans to households and non-financial corporations | Percentage

	% of total credit in Dec. 19	Dec. 19	Jun. 20	Dec. 20	Mar. 21	Jun. 21
Interest rates on loans						
Non-financial corporations (AAR)		2.1	2.1	1.8	2.0	2.0
Households - House purchase (APRC)		2.0	2.2	1.9	2.0	1.9
Households - Consumption (APRC)		8.8	9.0	8.4	8.5	8.6
Loans - Annual rate of change						
Households	100.0	1.7	1.5	1.8	2.2	3.2
House purchase	78.1	1.0	1.5	2.3	2.9	3.6
Consumption	16.2	7.7	4.1	0.5	-1.3	1.4
Non-financial corporations	100.0	0.4	5.6	9.8	10.0	6.3
of which: Size class:						
Very small firms	30.1	6.2	10.8	14.0	14.5	11.5
Small firms	23.9	-1.1	8.7	13.4	14.9	8.6
Medium firms	24.4	-1.9	4.3	6.2	7.1	2.6
Large firms	17.7	-3.1	-3.5	3.8	1.3	0.8
of which: Sector of economic activity:						
Manufacturing	18.3	0.2	5.0	9.6	16.0	10.2
Construction and real estate activities	23.9	1.8	3.5	5.5	5.5	3.8
Trade	17.2	2.2	8.2	9.6	9.8	5.1
Transportation and storage	7.5	-9.3	-9.2	0.4	4.7	3.5
Accommodation and food services	7.4	2.3	18.9	25.3	24.8	12.1
Professional and administrative activities	10.6	1.1	5.8	6.4	6.9	5.3

Source: Banco de Portugal. | Notes: The annual percentage rate of charge (APRC) is the total cost of the loan for the borrower, including interest and other (related) charges. Annual rates of change are based on the relation between end-of-month outstanding amounts and monthly transactions. Monthly transactions correspond to the difference in the end-of-month outstanding amounts adjusted for reclassifications, write-offs/write-downs, exchange rate and price revaluations, and any other price variations that do not correspond to financial transactions.

Chart I.2.3 • Bank loans granted to households and non-financial corporations under moratorium | Billion euros and segment percentage

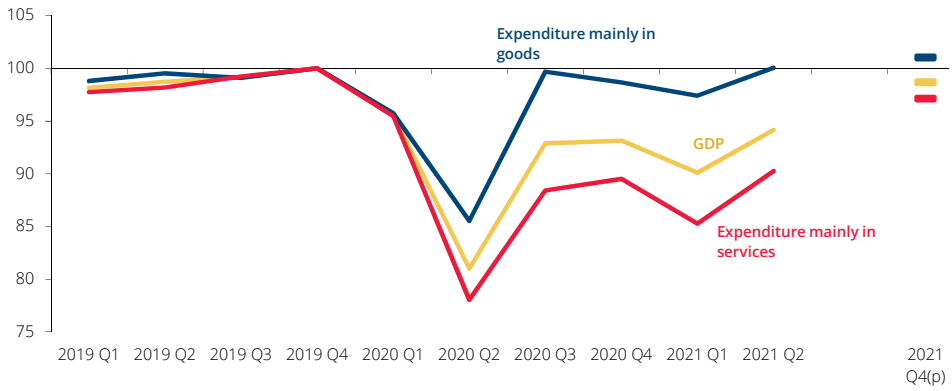


Source: Banco de Portugal. | Notes: Loans in the portfolio of financial sector entities supervised by Banco de Portugal (domestic activity). Amounts associated with contracts covered by moratorium (public or private).

3 Activity and external accounts

Underlying projected GDP growth is a recomposition of expenditure between goods and services, reflecting the differentiated impact of the pandemic crisis in sectoral terms (Chart I.3.1). In the first half of the year, activity showed again a marked profile as a result of the worsening health situation and the subsequent easing of restrictions (quarter-on-quarter rates of change of -3.3% and 4.5% in the first and second quarters). In sectoral terms, the fall in activity and the subsequent rebound were more marked in contact-intensive services (Table I.3.1). The projected recovery path until the end of the year embodies a greater momentum of expenditure on services. Nevertheless, expenditure on services will remain below pre-pandemic levels, given the persistence of precautionary behaviours, a slow recovery in tourism and the increased recourse to remote work. By contrast, at the end of 2021 expenditure on goods will stand above the pre-pandemic level, albeit constrained by supply-side disruptions.

Chart I.3.1 • GDP developments | Index, 2019 Q4 = 100



Sources: Banco de Portugal and Statistics Portugal. | Notes: (p) – projected. Expenditure mainly in services includes private consumption of services, public consumption, the share of services in investment, calculated from the information available in the supply and use tables, and exports of services. All components are net of imports, which means that they are obtained by subtracting an estimate of the imports used in each component. For more information on the methodology underlying this calculation, see Cardoso and Rua (2021) "Unveiling the real contribution of final demand to GDP growth", Banco de Portugal, *Economic Studies* – Vol. 7, No. 3.

By expenditure component, the recovery will be slower in exports, reflecting developments in the services component. At the end of 2021, exports of services will be almost 20% below the pre-pandemic level, while the remaining components will be close to or exceed this threshold (Table I.1.1). In the euro area, GDP will exceed the pre-pandemic level at the end of the year and is expected to grow by 5% in 2021 (-6.5% in 2020), according to the ECB's projections. In contrast to the projetions for Portugal, in 2021 GFCF in the euro area will stand below pre-pandemic levels, while exports will be close to that level (Chart I.3.2).

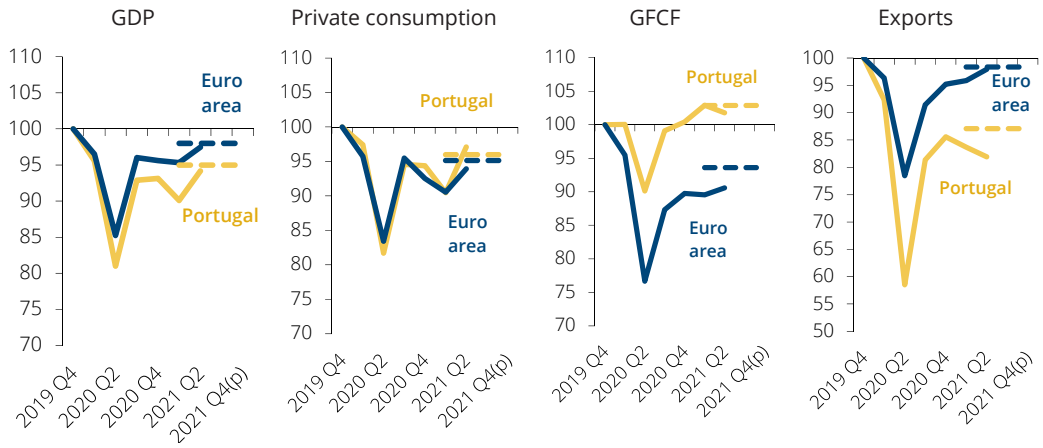
Private consumption will grow by 4.3% in 2021, sustained by disposable income growth and the gradual reduction in the savings rate, in a context of decreasing uncertainty. After falling by 4.1% in the first quarter due to restrictions and fears of infection, private consumption grew by 7.3% in the following quarter. This strong recovery reflected the easing of the containment measures and the realisation of postponed expenditure. A lower impact of these effects in the second half of the year will result in a slowdown in private consumption.

Table I.3.1 • Total GVA and subsectors | In percentage, unless otherwise stated

	Weights in 2020	Annual rate of change		Quarter-on-quarter rate of change						*Memo*: Index 2019 Q4 = 100	
		2019	2020	2020 Q1	2020 Q2	2020 Q3	2020 Q4	2021 Q1	2021 Q2	2019 Q4	2021 Q2
GVA	100.0	2.6	-7.2	-2.7	-14.3	13.7	0.4	-2.6	3.5	100	95.9
Agriculture, forestry and fishing	2.4	3.3	-5.9	-3.4	-1.9	-0.1	1.8	3.8	2.6	100	102.7
Industry (except construction)	17.4	0.5	-7.4	-1.9	-18.8	23.5	-1.0	-0.4	0.5	100	97.5
Construction	4.8	5.0	3.0	1.5	1.4	0.7	0.7	2.2	-0.5	100	106.1
Services	75.4	3.0	-7.8	-3.1	-14.5	12.8	0.7	-3.6	4.5	100	94.8
Trade, transport, accommodation and food services	20.8	3.0	-17.4	-5.8	-28.9	28.7	-2.5	-7.0	10.3	100	86.2
Information and communication	4.4	10.2	4.1	0.4	-1.9	3.3	2.7	0.4	3.4	100	108.5
Financial and insurance activities	18.7	1.4	-1.3	-0.4	-0.1	-0.2	-0.4	1.0	1.1	100	101.1
Administrative and support service activities	8.1	5.8	-9.7	-6.0	-25.1	24.9	9.4	-10.1	1.0	100	87.3
Public administration, education and health	20.7	2.1	-1.4	-2.0	-4.5	6.8	0.6	-1.5	3.2	100	102.2
Other services	2.7	3.1	-15.2	-0.4	-34.2	26.8	6.3	-6.4	5.2	100	87.0

Sources: Eurostat and Statistics Portugal.

Chart I.3.2 • GDP and main components in Portugal and in the euro area | Index, 2019 Q4 = 100

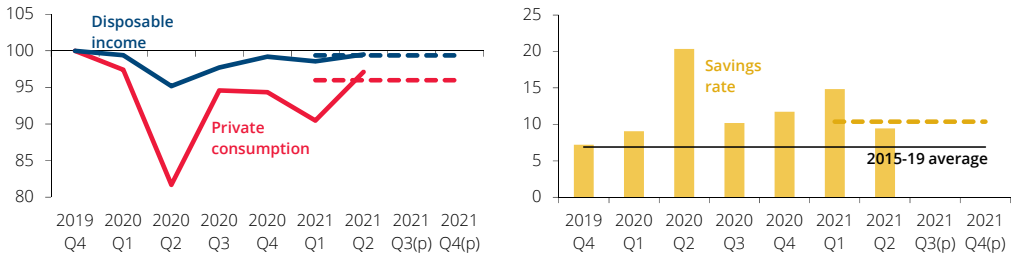


Sources: Banco de Portugal, ECB, Eurostat and Statistics Portugal. | Notes: (p) – projected. The dashed lines correspond to the Banco de Portugal and the ECB projections for 2021, for Portugal and for the euro area, respectively.

In 2021, real disposable income growth is linked to the strong rebound in employment and the momentum in nominal wages and is dampened by the increase in inflation. After declining by 0.6% in the first quarter, real disposable income grew by 1% in the second quarter. At the end of the first half of the year, this aggregate was close to pre-pandemic levels, also reflecting its resilience in the previous year (-1.1% in 2020) (Chart I.3.3). In this period, compensation of employees – reflecting the rapid and complete job recovery and wage growth – and social benefits surpassed the pre-crisis level, while corporate and property income stood below such level. In the second half of the year, real disposable income growth is projected to moderate, partly on account of higher inflation.

Households have accumulated significant savings since the onset of the pandemic. The savings rate increased further in the first quarter of 2021 (to 14.8%), as in the previous lockdown, partly reflecting involuntary savings stemming from limitations to consumption (Chart I.3.3). This rate declined in the second quarter (to 9.4%), but still remained well above the level observed in the years prior to the pandemic. Household savings continued to be channelled into deposits, which increased by 7% in annual terms in the first half of the year. In the second half of 2021, the savings rate is projected to decline, standing at 10.4% in the year as a whole, which compares with 7.2% in 2019.

Chart I.3.3 • Developments in disposable income, private consumption and savings rate
| Index, 2019 Q4 = 100 and percentage of disposable income



Sources: Banco de Portugal and Statistics Portugal. | Notes: (p) – projected. Private consumption and disposable income are presented in real terms. The private consumption defaltor was used to calculate real disposable income. The dashed lines correspond to the projection for 2021.

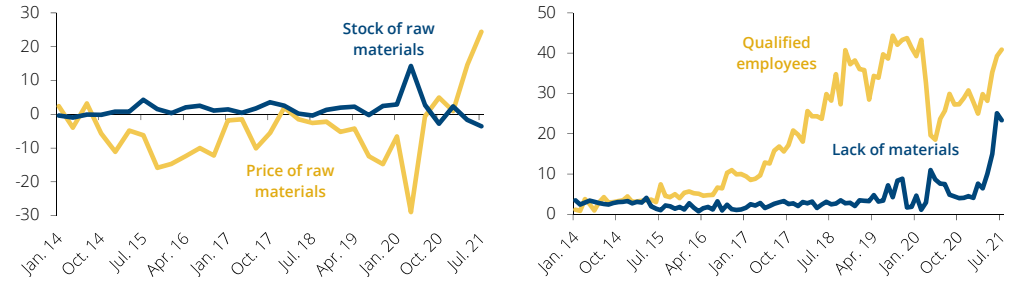
Public consumption is expected to grow by 5.2% in real terms in 2021, after nearly stabilising in 2020. This acceleration is mainly the result of an increase in hours worked compared with the first half of 2020, a period strongly affected by the pandemic. Underlying this estimate is an acceleration of expenditure on compensation of employees linked to the increase in the number of civil servants. Expenditure on purchases of goods and services is expected to increase mainly in the health sector, partly due to the vaccination process, which is largely financed by EU funds. On the other hand, the removal of restrictions on the operation of public services is likely to result in a recovery of sales in goods and services.

Investment will rise by 5.6% in 2021, supported by recovery prospects, EU funds and credit at low interest rates and with State-guarantees. Following a quarter-on-quarter growth of 2.5% in the first quarter, total GFCF declined by 1.1% in the second quarter. This is partly the result of difficulties in supply chains for commodities and other intermediate goods. In manufacturing, there was an increase in prices and a decline in stocks of raw materials, with the lack of qualified staff being seen as a growing constraint on activity (Chart I.3.4). In construction, there was also an increase in the share of firms pointing to limitations associated with material and labour force shortages. The housing construction cost index accelerated, year on year, from 2.7% in the first quarter to 6.1% in the second quarter.

Chart I.3.4 • Qualitative surveys' evidence from supply contraints

Panel A – Assessment of industrial raw material prices and stocks | Balance of respondents

Panel B – Limiting factors affecting production in construction | Percentage of companies reporting each factor



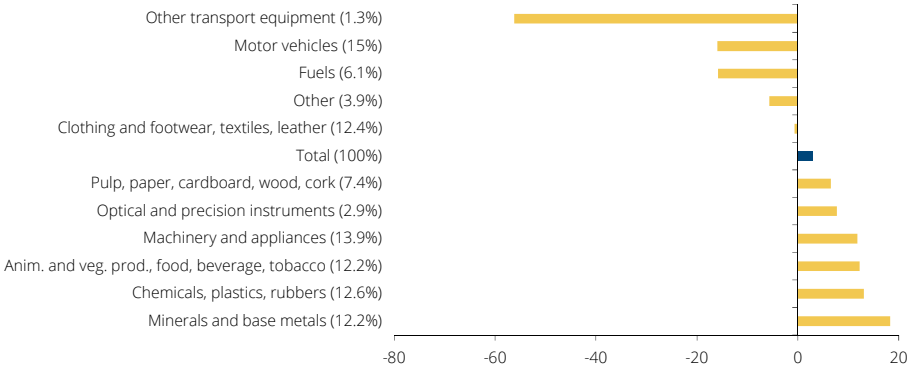
Source: Statistics Portugal, Business surveys.

In the second half of the year, investment will benefit from incoming EU funds. In particular, public investment is expected to grow in line with government's estimates, being also influenced by the local elections. Private investment is expected to increase by the end of the year, albeit limited by

the maintenance of supply constraints and the liquidity and solvency position of some firms in the sectors most affected by the pandemic.

Exports of goods will grow by 10.7% in 2021, in tandem with the buoyant external demand for Portuguese goods and services. Following a 2.1% quarter-on-quarter rate of change in the first quarter, goods exports declined by 5.3% in the second quarter. The external demand indicator for goods grew and the assessment of the external order book in industry continued to improve over the first half of the year, suggesting that the fall reflected supply disruptions. These had a strong impact on the car sector, where the number of vehicles produced for export fell in the second quarter (by 20.6% quarter on quarter, following a 4.1% increase in the previous quarter). Nevertheless, by the end of the first half of the year, most goods-exporting sectors had already recovered the pre-pandemic level of sales abroad (Chart I.3.5). During the pandemic, Portuguese exporters gained market share in the the main product/country markets in the EU (Box 3). For the second half of the year, exports of goods are expected to grow in line with external demand. However, disruptions in supply chains are likely to continue to affect some relevant sectors, leading to interruptions in production and decreases in trade flows.

Chart I.3.5 • Nominal exports of goods in 2021 Q2 | Percentage change from 2019 Q2

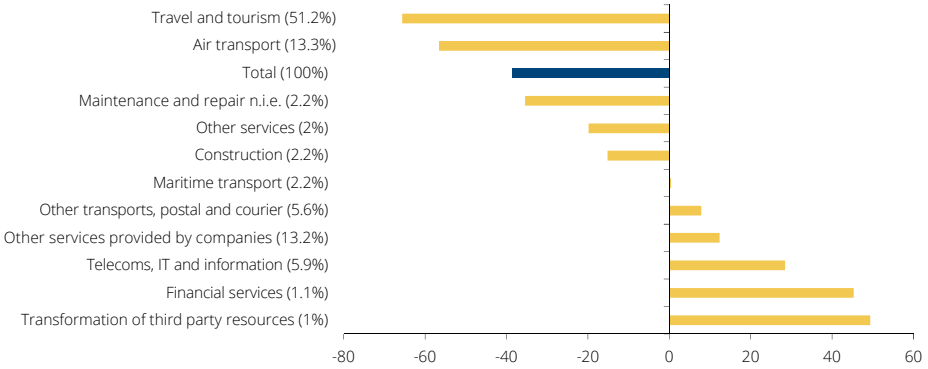


Source: Statistics Portugal. | Note: Percentages in brackets correspond to each component's weight in the total exports of goods, in 2019.

Exports of services remain constrained by the impact of the pandemic in 2021, growing by 7%, after a 37.2% decrease in the previous year. In the second quarter, exports of services increased by 8.2%, not recovering from the fall at the beginning of the year (14.2%). In particular, tourism exports fell by 34% in the first quarter due to the wave of infections in January/February and the recovery in the following months was constrained by the persistence of this effect. By the end of the half-year, tourism exports accounted for around 30% of their pre-pandemic level. Exports of other services have also not fully recovered, mainly reflecting the negative contribution from revenues of passenger air transport (Chart I.3.6). During the second half of the year a strong recovery in exports of services, in particular tourism and related services, is anticipated, reflecting the easing of international travel restrictions.

Imports of goods and services will grow by 9.7% in 2021, in line with final demand weighted by import content, approaching the pre-pandemic level in the fourth quarter, similarly to the components of domestic demand.

Chart I.3.6 • Nominal exports of services in 2021 Q2 | Percentage change from 2019 Q2



Source: Banco de Portugal. | Note: Percentages in brackets correspond to each component's weight in the total exports of services, in 2019.

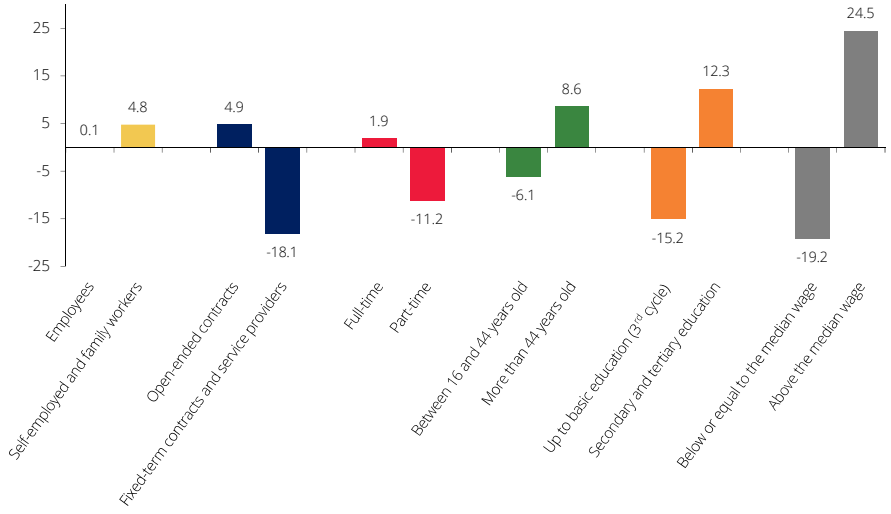
In 2021, the Portuguese economy will resume the sequence of external surpluses, with the current and capital account balance standing at 1% of GDP. The inflow of EU funds will contribute to an increase in income and capital account surplus from 1.8% of GDP in 2020 to 3.4% in 2021. This balance will also benefit from the reduction in public debt interest payments abroad and the reimbursement of €1.115 billion by the European Financial Stability Facility paid by Portugal under the Economic and Financial Assistance Programme. By contrast, the goods and services account deficit will increase in 2021 (from 1.8% of GDP to 2.3%). This behaviour is the result of a negative terms of trade effect related to an oil price increase and, to a lesser extent, a negative volume effect. The projected profile for tourism exports will contribute to a gradual increase in the services account surplus – more concentrated in the second half of the year –, but whose effect is not expected to be noticeable in 2021.

4 Labour market and prices

The labour market will pick up, with increases of 2.6% in employment and 8.4% in hours worked in 2021 (-1.9% and -9.3% respectively in the previous year). In the first half of 2021, employment, hours worked and labour force increased. By the end of this period, employment was already above pre-pandemic levels, but with mixed developments across various dimensions. The number of employed persons in the most affected services was below pre-crisis levels, in particular in trade, accommodation, food and transport services, as well as in activities related to arts and entertainment. By contrast, that number was above pre-crisis levels in construction, information and communication services, as well as in public administration, education and health services. The reallocation was the result of employing unemployed or inactive individuals in sectors of activity other than those in which they were previously employed and from a change of employment between sectors (Box 4). Compared with the pre-crisis period, the increase in employment in the second quarter was more marked for higher-skilled and higher-paid staff and favoured open-ended contracts (Chart I.4.1). By contrast, there was a fall in the employment rate of young people aged between 16 and 24, which was accompanied by an increase in the share of young people in education or training.

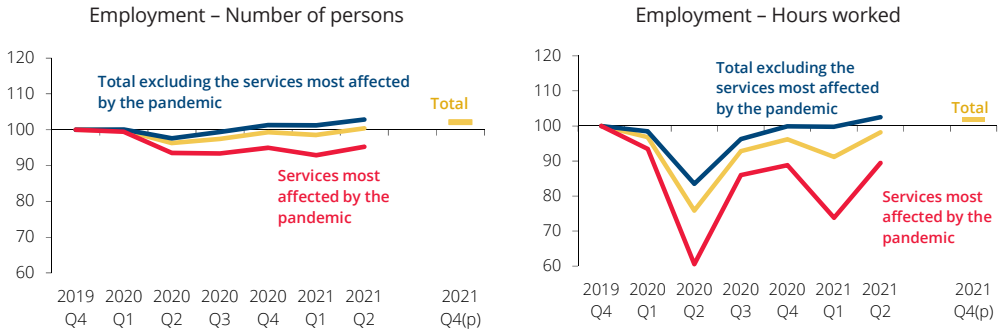
In the second half of the year, employment is expected to continue to grow, but at a slower pace. The negative impact of the pandemic on hours worked was more significant than the impact on employment, with a faster pace of growth being anticipated for hours worked until the end of the year (Chart I.4.2).

Chart I.4.1 • Employment by professional status, contract type, working time, age group, educational attainment and wage levels in 2021 Q2 | Percentage change from 2019 Q2



Source: Statistics Portugal – Labour Force Survey (Banco de Portugal calculations). | Notes: The series considered follow the 2021 Labour Force Survey methodology (for more details see the Press release and the additional information note (only available in Portuguese) at the Statistics Portugal website). Since the series considered are seasonally unadjusted, the percentage changes are computed regarding the same period of 2019.

Chart I.4.2 • Developments in employment | Index, 2019 Q4 = 100



Sources: Banco de Portugal and Statistics Portugal. | Notes: (p) – projected. The services most affected by the pandemic include wholesale and retail trade services, repair services of motor vehicles and motorcycles, transportation and storage, accommodation and food services, arts, entertainment and recreation services and other services (activity sectors G-I and R-U).

The unemployment rate and the labour underutilisation rate approached pre-pandemic levels in the first half of the year. The unemployment rate remained at around 7% in the first two quarters of 2021, compared with 6.7% in the first half of 2019. In turn, the labour underutilisation rate – which, in addition to the unemployed, includes part-time underemployed individuals, inactive jobseekers but not immediately available and inactive individuals available to work but not seeking employment – decreased, in particular in the second quarter (to 12.3%, from 12.7% in the second quarter of 2019). The sharp decline in the number of discouraged inactive individuals contributed to this decrease (Box 5).

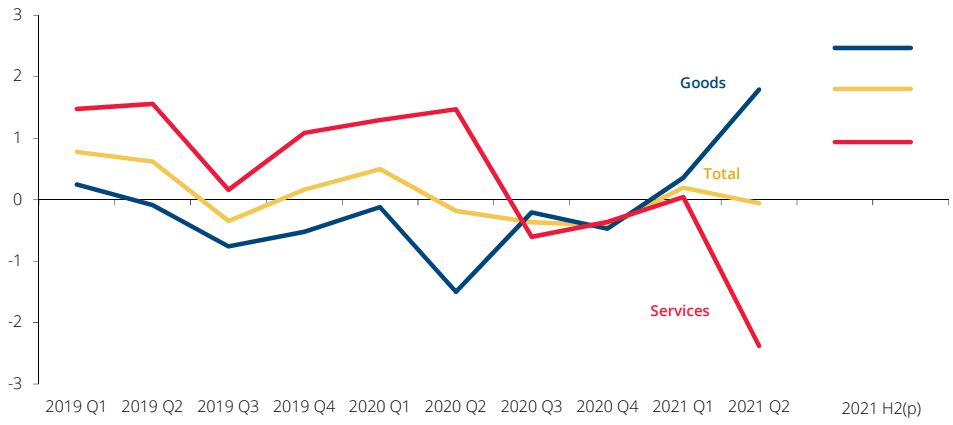
In 2021, the unemployment rate will edge down to 6.8% (7% in 2020), benefiting from the rebound in labour-intensive services. The lower impact of this crisis on the labour market is largely linked to the effectiveness of the support measures adopted, such as the "simplified layoff".

The reduction in available resources in the labour market will contribute to a strong increase in compensation per employee in 2021. After growing 2% in 2020 and 2.7% in the first quarter of 2021, compensation per employee grew by 5.6% year on year in the second quarter. However, these developments reflect the impact of employment protection schemes on wages. A comparison with the same period of 2019 – less affected by this effect given the small weight of employees covered by these measures in the second quarter of 2021 – shows that average compensation grew by around 6% in cumulative terms over the period. This behaviour reflected changes in the composition of employment, in favour of more skilled occupations, and shortages in labour supply. The rise of around 11% in the minimum wage between 2019 and 2021 also contributed to wage dynamism, particularly in view of the high share (around a quarter) of employees earning this compensation. In the second half of the year, more moderate growth in compensation per employee is projected.

Inflation remained low throughout the first half of 2021, with differentiated developments between goods and services. The year-on-year rate of change in the HICP stood at 0.2% and -0.1% in the first and second quarters (-0.1% in 2020 as a whole). These developments reflected the behaviour of services prices (-2.4% in the second quarter, following a stabilisation in the previous quarter), where final demand is still below the pre-crisis level. By contrast, goods prices increased by 0.4% and 1.8% in the first two quarters of 2021. These developments reflected the demand momentum – already approaching pre-crisis levels –, the problems in industrial supply chains and the recovery of oil prices.

In the second quarter, import prices of goods grew compared with the same quarter in the previous year (7.1% for total goods and 2.6% excluding energy), following the falls observed since the onset of the pandemic. In Portugal, the upward trend in production prices in industry is relatively broad-based but intermediate and energy goods stand out.

Chart I.4.3 • Developments in HICP | Year-on-year rate of change, in percentage



Sources: Banco de Portugal and Statistics Portugal. | Note: (p) – projected.

In the second half of the year, inflation will rise to 1.8%, supported by the recovery in services demand, supply problems and growth in energy prices (Chart I.4.3). Services prices will recover markedly in this period (0.9% year on year, from -1.2% in the previous semester), benefiting from the control of the pandemic and the recovery of tourism. Nevertheless, growth of the services component will still stand below that observed before the pandemic. Non-energy goods' prices will maintain the momentum observed in the second quarter, influenced by rising commodity prices,

import prices and transport costs. The HICP excluding energy will increase by 1.1% in the second half of the year (-0.2% in the first half). The projected developments for the energy component – increase of 10.2% year on year, compared with 3.8% in the first half of the year – reflect higher growth in oil and electricity prices. For the year, the rate of change of the HICP will stand at 0.9%, with the differential vis-à-vis the euro area widening from -0,4 p.p. in 2020 to -1,3 p.p.

5 Final remarks

In 2021 the Portuguese economy remains on the recovery path that started in the third quarter of 2020. By the end of the year, GDP will be close to that observed before the pandemic. The pandemic shock proved temporary, despite a more protracted impact on some sectors and firms. In these cases, there is a risk of accumulating situations of greater financial weakness, which may result in an increase in non-viable firms compared to 2019. The measures supporting firms' liquidity have been crucial but may have delayed the necessary adjustment of some companies. This adjustment process will continue to require the support of economic policies as well as the firms' capitalisation effort to allow the full resumption of business.

The balance of risks surrounding the projections for activity is skewed upwards. Downside risks associated with a deterioration in the health situation or a worsening of supply-side constraints will be more than offset by the possibility of a more dynamic reaction of agents to the lifting of containment measures, a faster reduction in the savings rate or a further decumulation of wealth. As for inflation, there are also upside risks associated with a stronger recovery in demand and a more significant increase in commodity costs. Transmission channels for consumer prices may be more active, with a higher pass-through of input costs, in a context of profit margin recovery.

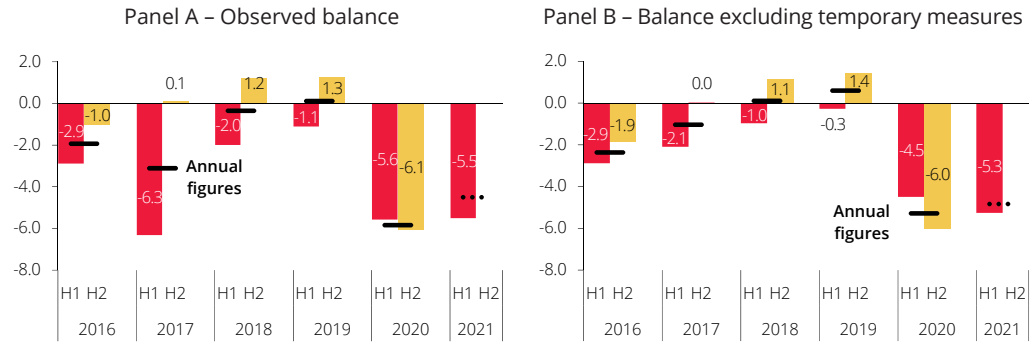
In a setting where support linked to the pandemic is more targeted to still affected sectors and to viable businesses, sustained growth in activity involves ensuring the preservation of productive capacity and an efficient reallocation of resources. Upcoming challenges include continued indebtedness reduction, notably in the public sector, the efficient use of financial resources made available to the country through the Recovery and Resilience Plan and the required reallocation of physical and human resources in response to digital and climate transitions (Special issue II). The recessionary period of 2020 had unique features, but also an unprecedented response of economic policies in Portugal and Europe. The adjustment of these policies and Portugal's success in addressing these challenges will contribute to both a stronger expansion of activity than that projected prior to the crisis and the return to convergence with the euro area.

Box 1 • Fiscal developments in 2021

In 2021 fiscal policy will continue to help in the recovery of economic activity and in the maintenance of labour market resilience through measures supporting households and firms.

In the first half of the year, the budget balance stood at 5.5% of GDP, very close to the figure recorded in the same period of the previous year. However, the impact of pandemic-related measures was higher: approximately 3%, compared with 1.9% in the first half of 2020 (Chart C1.1 – Panel A). The effect of temporary measures was less detrimental than in 2020 and, consequently, the balance adjusted for temporary effects deteriorated in year-on-year terms (Chart C1.1 – Panel B). In addition, interest expenditure declined as a percentage of GDP and the budgetary impact of automatic stabilisers also seems to have been less unfavourable.

Chart C1.1 • General government budget balance | In percentage of GDP



Sources: Statistics Portugal and Banco de Portugal. | Notes: Figures for each half of the year are in percentage of the GDP of the semester. For 2021, annual figures consider the official estimate included in the Stability Programme and confirmed in the second notification of the Excessive Deficit Procedure (-4.5% of GDP). In line with the Eurosystem definition, temporary measures with an impact on the first half of 2021 correspond to the capital injection by the Resolution Fund into Novo Banco and the recovery of the remainder of a guarantee granted to Banco Privado Português (which deteriorate the budget balance by 0.3% of GDP). In the second half of the year, they correspond to revenue related to the refund of margins previously paid to the European Financial Stability Facility (which improves the balance by 0.5% of GDP). For further details on operations considered in 2016-2020, refer to previous Banco de Portugal publications.

Primary expenditure as a ratio of GDP remained above its pre-crisis level, mainly owing to the impact of pandemic-related measures. In the first half of the year, general government primary expenditure reached 44.3% of GDP, which compares to 39.5% in 2019. Primary expenditure grew by 7.5% year--on-year. Spending on subsidies contributed significantly to this evolution reflecting the implementation of measures such as the Extraordinary Support for Progressive Resumption of Activity and the simplified layoff scheme. Social benefits in cash rose by 4.2% due to measures implemented in response to the pandemic, as well as increased expenditure on pensions and unemployment benefits. Compensation of employees grew by 4.5%, driven by a 3.3% increase in general government employment. Public investment increased by 29.4%, reflecting the implementation of projects with European funding, including the "Escola Digital" (Digital Schooling) Programme. The remaining components of primary expenditure rose by 2.6%.

General government revenue increased by 6.9%, boosted by the recovery of activity and inflows of European Union funds. The collection of taxes and social contributions grew by 3.9% reflecting the evolution of private consumption and the resilience of the labour market. Nevertheless, revenue from the personal income tax declined by 0.5% due to a higher concentration of refunds in the first half of

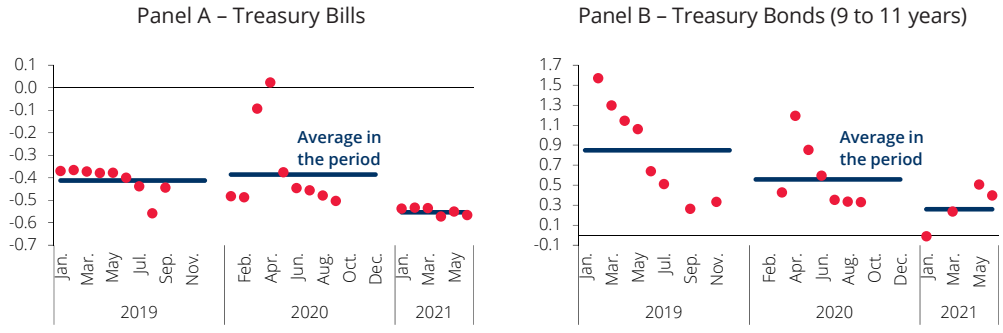
2021. The collection of the corporate income tax also decreased (-8.8%) as a result of the fall in revenue from final settlements, fully imputed to the first half of the year. Non-tax, non-contributory revenue rose by 24.1% due to the acceleration in inflows of European funds to finance pandemic-related expenses under the current community framework. Amounts were also received from the Recovery Assistance for Cohesion and the Territories of Europe initiative (REACT-EU) under the NGEU to finance the purchase of vaccines, among others.

Despite elevated uncertainty, the deficit target of 4.5% of GDP is attainable. Excluding the contribution of pandemic-related measures, general government expenditure continued to grow moderately, while developments in revenue were in line with forecasts underlying the Stability Programme. In addition, the seasonal pattern usually shows an improvement in the budget balance in the second half of the year (Chart C1.1). In 2021 this pattern should be reinforced by the reimbursement of fees previously paid to the European Financial Stability Facility (0.5% of GDP, already transferred in July) and by a lower concentration of personal income tax refunds. Finally, expenditure on pandemic-related measures is also expected to decline in the second half of the year. Conversely, the outturn until June only reflects approximately half of the amount foreseen for State aid to TAP in 2021 (0.2% of the foreseen 0.5% of GDP).

Considering the year ending in June, government debt stood at 135.4% of GDP, a figure similar to that observed at the end of 2020 (135.2%). This near stabilisation occurs against the background of an increase in the stock of debt, benefiting from a very significant denominator effect. Despite a decline in the stock of deposits, deficit-debt adjustments were positive (0.7% of GDP) in the first half of 2021, mostly reflecting time lags in the recording of taxes and advances of European funds without a counterpart on the expenditure side.

In line with developments in sovereign debt markets, the financing conditions of the Portuguese Republic remained favourable. The average interest rate in Treasury bill auctions stood at -0.6%, below the -0.4% recorded in 2019 and 2020 (Chart C1.2). Allotment yields in Treasury bond auctions in the first half of 2021 were generally lower than in the past two years. For bonds with an approximate maturity of 10 years, the average interest rate stood at 0.3%, compared with 0.8% and 0.6% in 2019 and 2020 respectively.

Chart C1.2 • Yields on public debt auctions | In percentage



Source: IGCP. | Note: The horizontal lines correspond to the average yield on public debt auctions in each period, weighted by the respective allotment amounts.

Box 2 • Access to credit by firms

Credit developments are a specific feature of the current pandemic crisis. This box analyses developments in bank loans to non-financial corporations since the start of the pandemic, in contrast to developments observed during the sovereign debt crisis. This is done using the methodology presented in Antunes and Martinho (2012), which makes it possible to assess developments in the volume of credit borrowed from banks, excluding observable and unobservable characteristics that are specific to the banking relationships of individual firms. This methodology thus allows for an assessment of developments in the "typical loan" amount over time in the Portuguese economy.

Formally, the analysis is based on the following equation:

$$y_{i,t} = \sum_{j} \alpha_j d_{j=i} + \sum_{u} \beta_u d_{u=t} + \epsilon_{i,t}$$

In this expression, i denotes the firm-bank relationship and t denotes the quarter of each year; $y_{i,t}$; is the amount of credit of banking relationship i at moment; t; $d_{j=i}$; is an indicator function for banking relationship i, and α_j is its coefficient; $d_{u=t}$; is an indicator function of date t, and β_u is its coefficient; and $\epsilon_{i,t}$ is an error term.

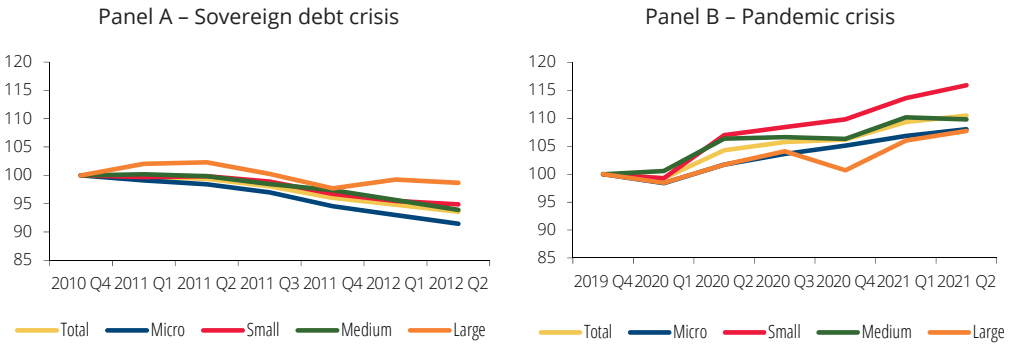
Coefficient α_j may be interpreted as the specific credit policy of a certain bank for a certain firm. Time coefficients β_u reflect developments in credit that are common to all banking relationships. These coefficients show developments in the average value of loans that are not explained by the idiosyncratic characteristics of each banking relationship, which might be due to changes in credit supply and demand. Given that these coefficients are estimated for all banking relationships, their aggregate developments translate developments in the "typical loan" amount in Portugal.

The model was estimated using data on credit balances at the end of each quarter, recorded in the Central Credit Register (CCR) of the Banco de Portugal from the first quarter of 2018 to the second quarter of 2021. These stock data are influenced by new loans and repayments. More recently, data reflect the suspension of repayments as a result of the moratoria.

Chart C2.1 shows time coefficients estimated for two different periods: from the fourth quarter of 2010 to the second quarter of 2012, corresponding to the peak of the sovereign debt crisis (Panel A); and from the fourth quarter of 2019 to the second quarter of 2021, covering the period of the current pandemic crisis (Panel B). The results obtained show that the "typical loan" amount declined by 6% during the sovereign debt crisis, while it increased by 11% during the pandemic crisis. The differing developments in the time coefficients reflect the different characteristics of the two crises. In the first case, it was a financial crisis characterised by a severe liquidity shortage and increased financial constraints. During the pandemic crisis, monetary policy and government support measures, specifically the moratoria and State-guaranteed credit lines, preserved favourable financing conditions.

In order to better understand the evolution of the "typical loan" amount in firms with different sizes and from different sectors, this methodology is applied to sub-samples of firms. During the sovereign debt crisis, the decline in the "typical loan" amount was broadly based across all firm sizes and particularly observed in smaller firms. During the pandemic crisis, "typical loan" amounts increased across all firm sizes, and in particular in small firms. The largest drop in the gross margin of smaller firms (See Special issue "The evolution of firms' liquidity during the pandemic" in the May 2021 issue of the *Economic Bulletin*) and greater access to credit through credit lines for SMEs benefited credit demand and the availability of loans to these firms.

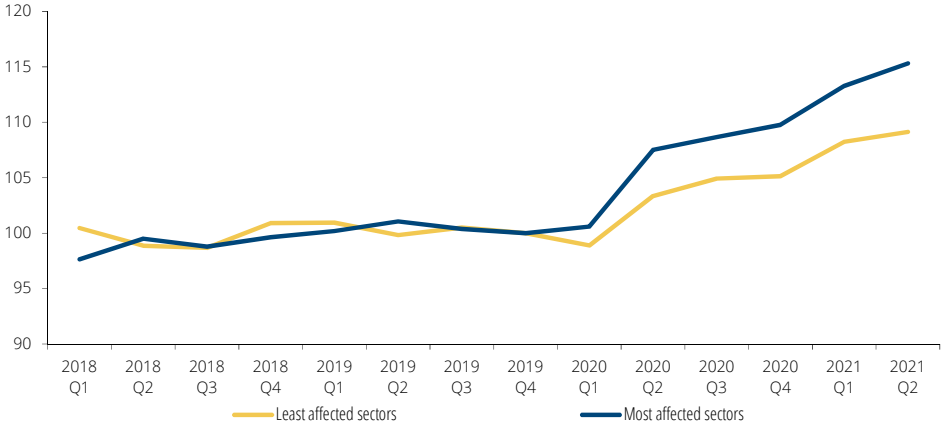
Chart C2.1 • Time dummies change over time by firm size | Index, 2010 Q4 = 100 and 2019 Q4 = 100



Source: Banco de Portugal (CCR). | Notes: The firm's classification follows the criteria of the European Commission Recommendation of 6 May 2003 on the definition of micro, small and medium-sized companies (2003/361/EC).

In the current pandemic crisis, developments in the loans' amount in the most affected sectors were more dynamic than in the other sectors (Chart C2.2). In comparison to the fourth quarter of 2019, the estimated "typical loan" amount increased by 15% for firms in the most affected sectors, and by 9% in the other sectors. This difference may be partly explained by the fact that a number of State-guaranteed credit lines are only available for the most affected sectors and that these sectors have a higher need for credit. The increase observed in firms belonging to the less affected sectors is influenced by the use of moratoria, which was higher in these firms.

Chart C2.2 • Time dummies change over time for the most and least affected sectors | Index, 2019 Q4 = 100

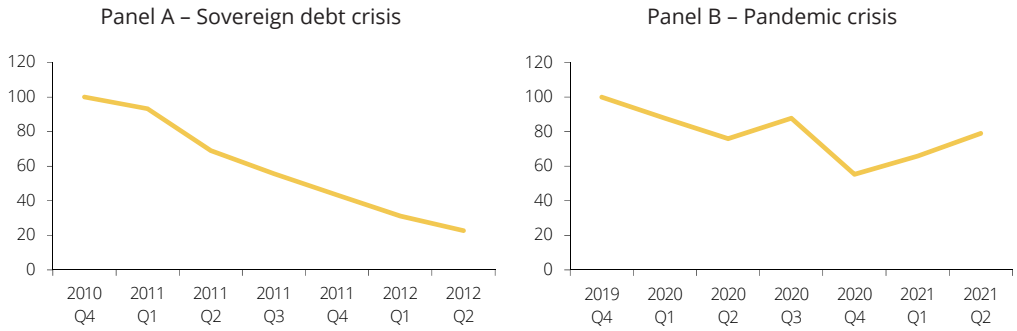


Source: Banco de Portugal (CCR). | Notes: The sectors most affected by the pandemic are defined according to the decree law number 22-C/2021 (some subsectors of retail trade, transportation, accommodation and food services, information and communication activities and other service.

In times of crisis, access to the credit market may be particularly difficult for new firms. For new firms (less than three years old), the analysis is based on the calculation of the median amount of loans granted to these firms in each quarter (Chart C2.3). In the current pandemic crisis, this value declined by 21%, a much lower decline than during the sovereign debt crisis (a 77% drop).

Developments in bank credit during the pandemic crisis were very different from those observed in the previous crisis. Recently, the "typical loan" amount increased and the size of loans to new firms declined much less than during the sovereign debt crisis.

Chart C2.3 • Change of the median amount of credit granted to new firms
| Index, 2010 Q4 = 100 and 2019 Q4 = 100

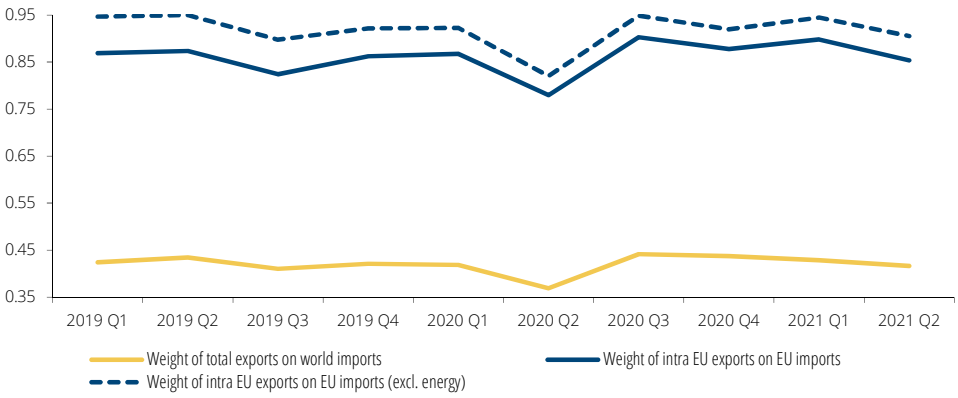


Source: Banco de Portugal (CCR). | Notes: A new firm is considered if the time between its inception and the credit concession date is a maximum of three years.

Box 3 • Developments in the market share of goods exports during the pandemic

The COVID-19 pandemic had a negative albeit short-lived impact on goods exports. Shares of Portuguese exports in the global market and the European Union (EU) declined in the second quarter of 2020, but recovered in the following quarter and have remained broadly unchanged since the end of 2020 (Chart C3.1). In the first half of 2021, and by comparison with the same period of 2019, the share of Portuguese exports (excluding fuel) decreased in the EU, owing to a negative effect from their specialisation that offset the positive effect related to market share gains in country/product markets.

Chart C3.1 • Weight of Portuguese exports in world and EU imports | Percentage



Sources: CPB, Eurostat and Statistics Portugal (Banco de Portugal calculations).

This box analyses the performance of Portuguese exporters of goods excluding fuel in the EU during the pandemic. Given that calculations are in nominal terms, the fuel component is excluded due to the sharp price fluctuations observed in this type of goods. Focusing on the EU market, with a 71% share in total exports of goods in 2019, allows for a detailed review by country/product. The constant market share methodology makes it possible to break down the difference between changes in exports of Portuguese goods and changes in EU imports (total effect) into two components: the market share effect and the combined structure effect. The market share effect assesses the impact of shifts in the share in each individual country/product market and is calculated based on the difference between the rate of growth of Portuguese exports and the rate of growth of imports in each individual market, weighted by the share of each individual market in total Portuguese exports to the EU. The combined structure effect assesses the effect of the relative specialisation of Portuguese exports in individual markets. The country's relative specialisation is measured taking into account the difference in the share of each individual market in total Portuguese exports and the share of that market in total EU imports. The specialisation pattern results in a positive (negative) contribution to the combined structure effect if imports in this individual market grow above (below) the average growth of imports in total markets under review.

In the first half of 2021, and by comparison with the corresponding period of 2019, the share of Portuguese exports excluding fuel in the EU market decreased, resulting in a total negative effect of -2.7 p.p. (Table C3.1). Underlying these developments is a combined structure effect of -4.5 p.p. and a market share effect of 1.8 p.p.

Table C3.1 • Change in the share of Portuguese exports of goods excluding energy to EU | Percentage and percentage points

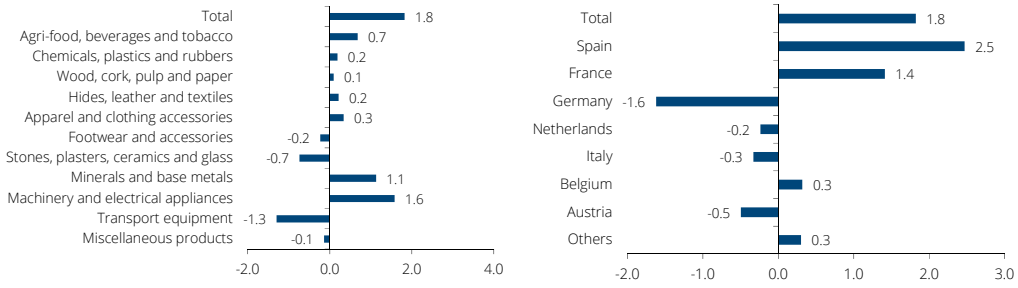
	2018	2019	2020	2021 H1 (Change *vis-à-vis* 2019 H1)
Intra EU Portuguese exports (y-o-y)	9.0	5.5	-8.1	3.5
EU imports (y-o-y)	4.9	2.6	-5.8	6.2
Total effect	4.0	2.9	-2.3	-2.7
Market share effect	4.3	3.0	0.8	1.8
Combined structure effect	-0.3	-0.1	-3.2	-4.5

Sources: Eurostat and Statistics Portugal (Banco de Portugal calculations). | Notes: In the analysis, were considered the imports of 26 EU partners, broken down by product (11 groups of products, defined from the Combined Nomenclature classification), resulting in 286 individual markets crossing country and product. Data is at nominal value therefore the changes in the share can be due to volume or relative price changes. Total effect is given by the difference between the growth rate of Portuguese goods exports to the EU and the growth of total goods imports from the EU. This effect can be broken down in market share effect that measures the impact of changes in the market share in each individual market (country/product); and a combined structure effect that assesses the impact of the relative specialization of Portuguese exports in individual country/product markets with growths different from the average of EU imports. For more details on the methodology see Amador, J. and Cabral, S. (2008), "The Portuguese export performance in perspective: a constant market share analysis", *Economic Bulletin*, Banco de Portugal, Autumn 2008.

The combined structure effect was particularly negative in the Spanish market for transport equipment and clothing and accessories. By geographic market, the negative effect of the specialisation in the first half of 2021 (compared to the same period of 2019) resulted from the concentration of exports in the Spanish market and, to a lesser extent, the French market, where changes in imports were 0.6% and 0%, respectively, compared with 6.2% growth in EU imports. By product, the negative structure effect is explained to a large extent by the relative specialisation of Portuguese exports on transport equipment, a market where EU imports fell by 9.0%, compared with the first half of 2019. The other sectors making a negative contribution to the structure effect were clothing and accessories, and machinery and electrical appliances. In the case of clothing and accessories, a market with a larger relative share in Portuguese exports, EU imports declined. In contrast, the market for machinery and electrical appliances, where Portugal is not specialised, grew above the EU average.

The positive market share effect points to a greater ability of Portuguese exporters to compete with other suppliers in several country/product markets during the pandemic. By geographic market, the market share gains in Spain and France stand out (Chart C3.2). By product, the good performance of exporters was relatively broadly based, with market share gains in machinery and electrical appliances, minerals and base metals and agri-food, beverages and tobacco making a particularly significant contribution.

Chart C3.2 • Breakdown of the market share effect in 2021 H1 | Change vis-à-vis 2019 H1 as percentage and contribution of country and product market in percentage points



Sources: Eurostat and Statistics Portugal (Banco de Portugal calculations).

Box 4 • Sectoral reallocation of employment in the context of the pandemic

The differing impact of the crisis has led to considerable changes in employment in the various sectors of activity. In general, a significant share of the sectoral reallocation of employment can result from the re-employment of individuals in sectors of activity other than those they initially belonged to, or from the differing impact by sector of activity of employment outflows. Another potential source of reallocation results from workers who have moved to a different job in a different sector.

Compared to the previous recession, sectoral quarterly flows between employment and unemployment/inactivity have declined. An analysis of the dynamics of transitions between employment and unemployment shows lower average cross-sectoral quarterly flows both in gross and net terms, with the exception of accommodation and food and other services (Table C4.1). This decline reflects the support measures such the simplified "layoff" scheme, which have limited job destruction and the rise in the unemployment rate. Cross-sectoral employment flows are similar in size in both recessions (Table C4.1, line – employment-employment net flows).

Table C4.1 • Quarterly average flows to employment by sector of activity in the period from 2020 Q1 to 2021 Q2 | Thousands of individuals

					Services			
	Agriculture and animal production	Industry (including energy)	Construction	Services	Trade	Accommodation and food service activities	Information and communication	Other services
Net flow to employment (1)-(2)	0.0	-1.2	1.7	-1.3	1.1	-6.8	2.2	2.2
Gross flow non-employment to employment (1)	40.8	18.7	9.6	105.0	21.2	14.1	3.6	66.0
Gross flow employment to non-employment (2)	40.8	19.8	7.9	106.3	20.1	20.9	1.4	63.9
Net flow employment to employment [(a)]	0.7	-1.2	1.7	-1.2	-4.1	-0.1	3.2	-0.3

Memo: **Quarterly average flows in the period from 2011 Q1 to 2013 Q4:**

					Services			
	Agriculture and animal production	Industry (including energy)	Construction	Services	Trade	Accommodation and food service activities	Information and communication	Other services
Net flow to employment (1)-(2)	3.1	-3.2	-7.0	-2.1	-3.0	-0.2	0.3	0.9
Gross flow non-employment to employment (1)	100.3	20.4	15.6	112.6	23.0	19.4	2.7	67.4
Gross flow employment to non-employment (2)	97.1	23.6	22.5	114.6	26.0	19.6	2.5	66.5
Net flow employment to employment [(a)]	1.9	0.6	-1.6	-0.9	-2.1	0.5	-0.7	1.4

Source: Statistics Portugal – Labour Force Survey (Banco de Portugal calculations). | Notes: (a) Quarterly average net flows of individuals that change job to different sectors (sector of destination). The values correspond to quarterly average flows in the periods indicated. They are based on constant sample calculations (individuals that remain in the sample for two consecutive quarters).

During the pandemic, flows between labour market states contributed, on average, to an increase in employment in construction and a decrease in industry and services. This is in contrast to the pre-pandemic period, where net employment flows in the services sector increased,

in particular in accommodation and food services. The accommodation and food services sector made a significant contribution to the fall in employment in services during the pandemic, partially offset by employment gains in trade, information and communication and other services. A considerable share of the workers who left the accommodation and food services sector during the pandemic moved to inactivity or unemployment (an average of 6,800 in net terms each quarter). Note that, in the previous recession, the negative impact on employment from labour market flows was more broad across the various sectors of activity, although construction was particularly affected.

The sectoral dynamics of flows to employment was reinforced by transitions of persons employed who changed jobs between sectors during the pandemic. In net terms, these flows led to an increase in employment in agriculture and animal production and in construction and to a decline in industry and services (Table C4.1, last line, employment-employment flows). In services, employment increased in the information and communication sector, reflecting net inflows from unemployment or inactivity as well as workers from other sectors – in line with the growth observed in this sector during the pandemic. In contrast, significant net outflows were observed in trade.

Table C4.2 • Quarterly average net flows of individuals that change job to a different sector in the period from 2020 Q1 to 2021 Q2 | Thousands of individuals

			Sector of destination					
					Services			
			Industry (including energy)	Construction	Trade	Accommodation and food service activities	Information and communication	Other services
Sector of origin		Agriculture and animal production	-0.9	-0.2	0.2	0.5	0.0	-0.2
		Industry (including energy)	–	-0.1	-0.7	-0.2	1.7	-0.4
		Construction	–	-	-1.1	-0.4	0.5	-0.9
	Services	Trade	–	–	–	0.2	0.7	1.4
		Accommodation and food service activities	–	–	–	–	-0.1	0.3
		Information and communication	–	–	–	–	–	-0.4

Memo: **Quarterly average net flows in the period from 2011 Q1 to 2013 Q4:**

			Sector of destination					
					Services			
			Industry (including energy)	Construction	Trade	Accommodation and food service activities	Information and communication	Other services
Sector of origin		Agriculture and animal production	-0.3	-0.4	-0.9	-0.2	0.0	0.0
		Industry (including energy)	–	-0.2	-1.1	0.1	0.1	0.3
		Construction	–	-	0.0	-0.2	-0.2	1.3
	Services	Trade	–	–	–	-0.3	-0.8	1.2
		Accommodation and food service activities	–	–	–	–	-0.2	-1.0
		Information and communication	–	–	–	–	–	-0.4

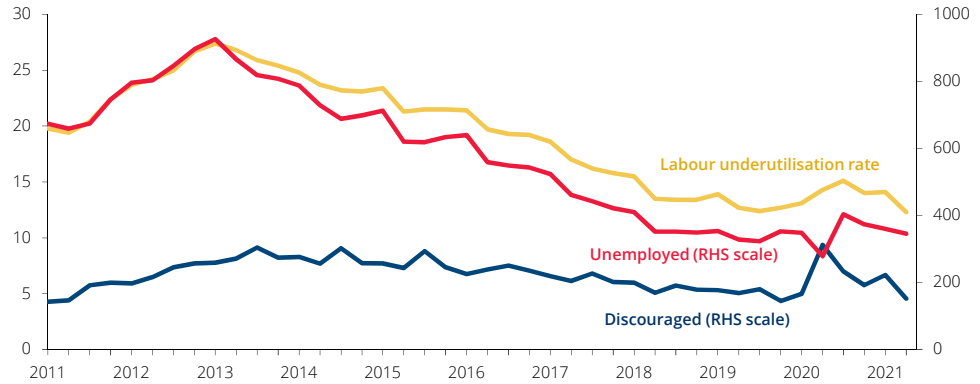
Source: Statistics Portugal – Labour Force Survey (Banco de Portugal calculations). | Notes: The values correspond to quarterly average flows in the periods indicated. They are based on constant sample calculations (individuals that remain in the sample for two consecutive quarters). Each value in the table corresponds to the differences between the gross worker outflow from sectors indicated in rows (origin) to the sectors indicated in columns (destination) and the reverse gross inflow. As an example, the negative net outflow between Agriculture (origin) and Industry (destination) means that this specific flow has generated an increase of workers in Agriculture and a reduction in Industry.

The decline in employment in services was mainly the result of net outflows of workers to construction, while the fall in employment in industry was largely due to net outflows to information and communication, and to agriculture (Table C4.2).

Box 5 • A characterisation of developments in discouraged individuals during the pandemic

Developments in labour underutilisation during the pandemic were highly influenced by changes in the number of discouraged individuals, non-employed individuals who, although available for work, did not actively seek work (Chart C5.1).

Chart C5.1 • Labour underutilisation rate and number of discouraged and unemployed
| Percentage and thousands of individuals



Source: Statistics Portugal – Labour Force Survey. | Note: Labour underutilisation is an indicator that aggregates the unemployed population, the underemployment of part-time workers, the inactive seeking work but not immediately available, and the inactive available but not seeking work. All these population groups consider the age group 16 to 74.

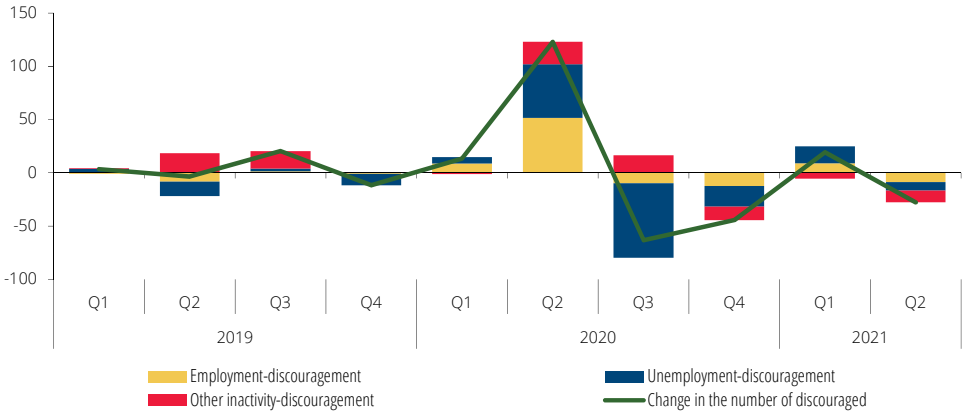
At the start of the pandemic, the number of discouraged increased by approximately 150,000, which is unprecedented in terms of magnitude and speed. In the following two quarters, this increase saw a sharp reversal, which was completed by the second quarter of 2021. The number of discouraged was particularly high at times when containment measures were tighter, namely in the second and third quarters of 2020 and the first quarter of 2021. Part of these were individuals who would be classified as unemployed under normal circumstances. They were classified as inactive because they did not actively seek work owing to restrictions on mobility and the decrease or interruption of normal job-search channels associated to the stoppage of business activity.

In the second quarter of 2020, the increase in discouraged was the result of transitions of previously employed and unemployed workers that were similar in size (Chart C5.2). An analysis of gross quarterly flows with a constant sample shows that, of the newly discouraged who were previously employed, 68% came from services (17.2% from accommodation and food services and 15.0% from trade) and 56.1% had a level of school attainment equal to or less than primary education. These figures compare with 76.4% and 38.3%, respectively, for the newly unemployed. In this quarter, the most represented age groups in newly discouraged were those aged from 16 to 34 (39.7%) and from 35 to 54 (40.9%). Most newly discouraged (64%) who had been employees had been in precarious employment, namely fixed-term contracts or contracts for the provision of services.

Despite still exhibiting some volatility, there were considerable transitions of discouraged to unemployment and employment in the following quarters. At the end of the first half of 2021, the breakdown of discouraged by education and age showed a number of changes from the figures observed in the second quarter of 2019 (Chart C5.3). The median age increased from 44 to 48 years old and average schooling also increased. In particular, the share of discouraged with

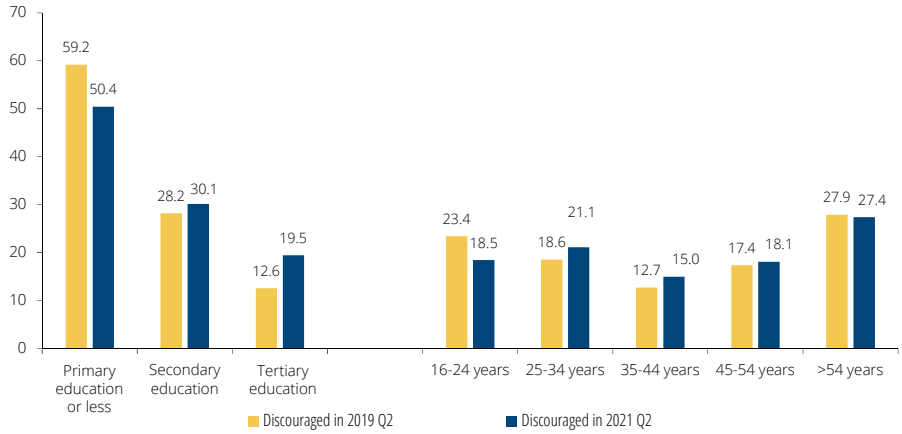
tertiary education rose from 12.6%, in the second quarter of 2019 to 19.5%, in the second quarter of 2021. As regards the newly discouraged who were previously employed, the average share of those employed in the services sector increased. Compared with the average flows in the period 2015-19, this share rose from 59% to 70%. In particular, the average share of newly discouraged coming from trade increased from 11.5% to 14.5%, and from accommodation and foods services from 10.7% to 13.8%. Conversely, the average share of newly discouraged individuals coming from agriculture declined from 21.9% in the period 2015-19 to 11.2%.

Chart C5.2 • Change in the number of discouraged and contribution from the main labour market flows | Quarterly net flows based on constant sample, thousands of individuals



Source: Statistics Portugal – Labour Force Survey (Banco de Portugal calculations). | Notes: Labour market flows are based on constant sample calculations, i.e. considering only the individuals that remain in the sample for two consecutive quarters. For this reason, these changes do not coincide with those presented in Chart C4.1.

Chart C5.3 • Characterization of discouraged by education and age in the second quarter of 2019 and in the second quarter of 2021 | Percentage of total discouraged



Source: Statistics Portugal – Labour Force Survey (Banco de Portugal calculations).

II Special issue

The ECB's new monetary policy strategy

Climate change and the economy

The ECB's new monetary policy strategy

Introduction

Since the last review of the monetary policy strategy of the European Central Bank (ECB) in 2003, the euro area economy has faced profound structural and institutional changes, partly as a result of the crises it has experienced. The protracted environment of low inflation, low potential growth and low natural interest rate have characterised the post-crises period.

In order to find the best way to fulfil its mandate in this new context, the ECB launched an in-depth, comprehensive review of its monetary policy strategy in January 2020. That same year, similar exercises were in progress or being prepared in other central banks, such as the US Federal Reserve, the Bank of England or the Bank of Canada.

In July 2021, the ECB concluded the review and presented its new monetary policy strategy, which is expressed in three documents: "The ECB's monetary policy strategy statement"[1] ("Statement"), comprised of 12 paragraphs conveying the essential points of the new strategy; "An overview of the ECB's monetary policy strategy"[2], which expands on the reflection that underpins it; and "ECB presents action plan to include climate change considerations in its monetary policy strategy".[3] These final products of the strategy review combine continuity and adaptation, represent a compromise between the multiple points of view explored and have been unanimously agreed by the Governing Council.

The announcement of the new strategy ended an 18-month process of interaction and analysis, organised into 13 thematic working groups and involving staff from the ECB and the Eurosystem's national central banks.[4] There were also several listening events with stakeholders in the 19 euro area countries, including academia and the general public. The Banco de Portugal held three such events:[5] one of them specifically for academia, which had 245 participants from 19 economics and management schools located in Portugal; a second for civil society organisations, including trade unions, consumer and environmental organisations, employers' associations and foundations; and a third for journalists.

This article briefly describes the evolution of the ECB's monetary policy strategy and delves into the key elements of the new strategy, focusing on the paragraphs of the Statement. The Special issue "The European Central Bank's monetary policy strategy: reasons for a review" in the June 2020 issue of the *Economic Bulletin* discusses in greater depth the motivations for this review and provides a more detailed analysis of the evolution of the strategy since its initial design (Banco de Portugal, 2020).

1. https://www.ecb.europa.eu/home/search/review/html/ecb.strategyreview_monpol_strategy_statement.en.html.
2. https://www.ecb.europa.eu/home/search/review/html/ecb.strategyreview_monpol_strategy_overview.en.html.
3. https://www.ecb.europa.eu/press/pr/date/2021/html/ecb.pr210708_1~f104919225.en.html.
4. To learn more about the main topics of the review, the challenges surrounding each one and the way in which they were addressed, see: https://www.ecb.europa.eu/home/search/review/html/workstreams.en.html.
5. For further details, see the dedicated webpage on the Banco de Portugal's website: https://www.bportugal.pt/en/page/review-european-central-bank-monetary-policy-strategy.

Evolution of the ECB's monetary policy strategy

A monetary policy strategy serves the purpose of producing a framework for central bank decision-making so as to enable a consistent, systematic approach in terms of both the pursuance of its statutory objective and communication with the public. The strategy drawn up by the ECB in October 1998 performed this function in the context of the transition to Stage Three of the Economic and Monetary Union (EMU). The credibility of the newly created central bank was established by continuing the successful strategies used by euro area central banks and by adopting a communication policy to explain to the public the reasoning behind decisions. The strategy included some key elements: a quantitative definition of price stability; assigning a prominent role to money, establishing a reference value for the growth of a monetary aggregate; a broadly-based approach to analyse the outlook for inflation and the risks to price stability, using a wide range of economic and financial variables.[6]

The definition of price stability is important for the coordination of medium to long-term inflation expectations and provides a benchmark for assessing the policy's performance. In 1998, it was determined that price stability was to be maintained over the medium term and would be defined as a year-on-year increase in the Harmonised Index of Consumer Prices (HICP) for the euro area of below 2%. Opting for this upper threshold was justified by theoretical and empirical arguments in favour of a positive, low level of inflation (Adão, 2019), as well as the past practice of most euro area central banks. The purpose of the medium-term orientation was: (i) to take into account the large, variable lag with which monetary policy actions influence prices, and (ii) to acknowledge that there may be short-term price volatility that cannot be controlled by monetary policy.

In May 2003, the ECB's monetary policy strategy was reviewed in light of the experience gained and taking into account a wide range of points of view from academics, market participants and other observers. A number of clarifications were made, mostly to increase the effectiveness of communication. In that review, the Governing Council confirmed the definition of price stability, clarifying that it intended to keep inflation below, but close to, 2% over the medium term. The focus on the upper end of the range between 0% and 2% had several advantages: it was consistent with inflation expectations hitherto between 1.7% and 1.9% (ECB, 2003); it contributed to the establishment of a safety margin against deflation risks and the uncertainty about a possible positive statistical bias in the HICP; and it made it possible to accommodate inflation differentials across euro area countries.

Another distinctive feature of the revised strategy, which confirmed the practice followed since 1998, was the two-pillar approach to assess the outlook for inflation and the risks to price stability. These two – distinct but complementary – pillars focused on different determinants of inflation: one gave prominence to the role of monetary aggregates (monetary pillar) while the other attached greater relevance to the interplay between supply and demand in goods and services markets and in the labour market (economic pillar). In 2003, the ECB clarified how the monetary and economic pillars should complement one another: the economic analysis would identify short to medium-term risks to price stability, while the monetary analysis would cross-check, from a medium to long-term perspective, the indications coming from the economic analysis. The prominence attributed to money in 1998 therefore came to a halt, and the annual review of the reference value for monetary growth was *de facto* discontinued.

6. For further details, see the dedicated webpage on the ECB's website: https://www.ecb.europa.eu/press/pr/date/1998/html/pr981013_1.en.html.

The 2003 review further clarified that, within its medium-term orientation, monetary policy should respond flexibly to different types of economic shocks. Indirectly, this would allow the ECB to take into account considerations other than price stability, such as avoiding unwanted volatility in economic growth or employment.

The challenges faced over the last two decades have required gradual adjustments to the monetary policy strategy. Over the past few years, characterised by inflation below the objective, perceptions of asymmetry in relation to this objective have remained (Hartmann and Smets, 2018), according to which the ECB would have a higher tolerance for below-objective inflation than for above-objective inflation. ECB officials sought to dispel these perceptions in successive speeches (Draghi, 2016) and, in July 2019, the Governing Council's commitment to symmetry in its objective was outlined in the introductory statement to the communication of monetary policy decisions. However, those perceptions may have persisted. Another, more fundamental, challenge was related to the impact of the 2008-09 global financial crisis and the 2011-13 sovereign debt crisis, particularly on the financial system, which affected monetary policy transmission. In this context, the scope of the monetary analysis has expanded to include credit, financial intermediation, asset price developments and the identification of risks to financial stability. The focus of this analysis has progressively shifted to the monetary policy transmission mechanism. The strong interplay between financial and real factors has strengthened the link between the economic and monetary analyses. Although both pillars were kept in the structure of the introductory statement, references to the monetary pillar lost prominence in the public communication of ECB officials.

Due to the crises and structural dynamics such as productivity slowdown or population ageing, the euro area economy has faced an environment of low potential output growth, low inflation rates and low real and nominal interest rates. This weighs on the conduct of monetary policy, first and foremost by limiting the room for a decrease in nominal interest rates (Brand, Bielecki and Penalver, 2018). The response to these constraints has made clear the need to review the monetary policy strategy.

The new strategy

The Statement presented in 8 July 2021 begins precisely by identifying the new environment of low potential growth, low inflation and low interest rates as the overriding motive for the current review. Taking this document as a reference, this section explores the main outlines of the new strategy, which will frame monetary policy decisions in the coming years. More specifically, the following dimensions of the new strategy will be discussed:

- The commitment to the ECB's mandate and the assessment of compliance with its primary objective, entailing the choice of an inflation measure and an inflation target; the recognition of additional attributions and the medium-term orientation of monetary policy;
- The challenges that the effective lower bound on interest rates poses to the fulfilment of the mandate and the resources available to address them, including the expanded monetary policy toolkit;
- The way in which the ECB substantiates and communicates monetary policy decisions, including the interplay between the economic analysis and the (now called) monetary and financial analysis;
- The contribution to climate change mitigation;
- And, finally, the commitment to periodically assess the monetary policy strategy.

For some of these dimensions, the relevant paragraphs of the Statement will be reproduced.

Mandate

The new strategy restates the commitment to the mandate conferred by the Treaties and to the primary objective of price stability. At the same time, other important attributions are recognised and should be pursued without prejudice to price stability: support for general economic policies in the Union, with a view to contributing to the achievement of the objectives of the Union, and contribution to the smooth conduct of policies pursued by the competent authorities relating to prudential supervision and the stability of the financial system (Article 127 of the Treaty on the Functioning of the European Union). The objectives of the Union include balanced economic growth, a highly competitive social market economy aiming at full employment and social progress, and a high level of protection and improvement of the quality of the environment. By making these attributions explicit, the new strategy confirms their observance in actual monetary policy decisions and helps the public to understand these decisions.

It should be noted that the ECB's contribution to the Union's objectives is achieved by supporting the general economic policies in the Union. Admittedly, therefore, the ECB's pursuit of objectives in addition to the primary objective denotes the existence of general policies in the Union which are economically relevant (not necessarily economic policies in the strict sense) and pursue those objectives.[7] Support for such policies shall respect, in particular, the principle of proportionality.

Medium-term orientation

> The Governing Council confirms the medium-term orientation of its monetary policy strategy. This allows for inevitable short-term deviations of inflation from the target, as well as lags and uncertainty in the transmission of monetary policy to the economy and to inflation. The flexibility of the medium-term orientation takes into account that the appropriate monetary policy response to a deviation of inflation from the target is context-specific and depends on the origin, magnitude and persistence of the deviation. It also allows the Governing Council in its monetary policy decisions to cater for other considerations relevant to the pursuit of price stability.
>
> Paragraph 7 of the Statement

An important element kept in the monetary policy strategy is the medium-term orientation (Paragraph 7 of the Statement), i.e. the specification that the inflation target must be met over the medium term. Thus, it is once more recognised that it is not feasible or even desirable to maintain inflation at a given level at each point in time. This impossibility is due to the constant shocks to which the economy is subject and the time it takes for monetary policy to have an effect, combined with the uncertainty of its impact. On the other hand, even if an inflation target could be met at all times, this could imply very marked changes in interest rates and economic activity, which could lead to significant welfare costs.

The medium-term orientation allows the ECB to cater for other considerations within its mandate, provided that price stability is ensured. This flexibility is desirable in the face of numerous conceivable contexts. For instance, in the case of supply shocks that move inflation and output in the opposite

7. See Chapter 3 in Abreu and Valle e Azevedo (Eds.), 2021.

direction, an aggressive monetary policy response could destabilise activity and employment. The medium-term orientation allows to prevent this. However, it should be noted that the wording chosen in this Paragraph to cater for considerations other than the primary objective can be seen as restrictive, since it only refers to "other considerations relevant to the pursuit of price stability".

The medium-term orientation is particularly important in the post-pandemic period. Relevant supply-side constraints, together with robust demand growth, can result in significant – albeit temporary – increases in inflation. A premature withdrawal of monetary policy stimuli could jeopardise a swift recovery of the economy and lead to unwanted effects on inflation at longer horizons.

Inflation measurement

Without prejudice to continuous improvement, it was concluded that the HICP remains the most appropriate price index for measuring inflation. This adequacy is assessed in the light of criteria of timely update and disclosure, reliability (sparse need for revisions), comparability (across periods and countries) and credibility (matching the cost of living as perceived by the public). Since 2003, Eurostat and the national statistical authorities of the European Union (EU) Member States have improved the calculation of this index, notably as regards harmonisation across countries, sampling, coverage and timeliness.

The new strategy acknowledges, however, the need to include more comprehensively the costs of owner-occupied housing (OOH) in the HICP. This adjustment will improve the representativeness of the consumer basket, which currently only includes rents and minor repairs, and cross-country comparability, given the heterogeneity in house ownership rates across the euro area. Concerns about these costs were raised by the public in the listening activities that the Eurosystem carried out as part of the monetary policy strategy review (ECB, 2021).

Including OOH costs in the HICP poses several challenges. For instance, the HICP conceptually focuses on household final consumption expenditure that involves monetary transactions. However, a dwelling typically generates monetary transactions only when it is built or sold and can moreover be traded for investment rather than final consumption purposes. In addition, OOH costs are currently disseminated less frequently and more slowly than the HICP.

This amendment to the HICP will therefore be prepared gradually over the coming years in partnership with Eurostat. In the meanwhile, the HICP in its current format will remain the key measure to monitor price stability, whilst also using the available information on OOH costs.

Inflation target

The Statement on the new strategy lists the arguments that support the adoption of a strictly positive inflation target. The decline observed in equilibrium real interest rates is one of them. Given that nominal interest rates will tend to correspond to the sum of real interest rates and inflation expectations, maintaining positive inflation expectations provides additional room to support higher nominal interest rates. This makes room for monetary accommodation in the event of adverse shocks, which is particularly critical in a context where nominal interest rates may more frequently reach the effective lower bound (ELB) on interest rates (Andrade, Galí, Le Bihan and Matheron, 2019; Ball, 2014; Williams, 2009). The arguments used in 2003 in favour of maintaining strictly positive inflation rates are also repeated: to facilitate cross-country macroeconomic adjustment within the euro area (preventing countries with below-average inflation from facing deflation), to facilitate real wage adjustments (in a context of downward nominal wage rigidities) and to accommodate possible statistical biases when measuring inflation.

In the 2003 strategy review, the definition of price stability pointed to a strictly positive change in the HICP in the euro area, but below 2%, suggesting an upper threshold for the desirable growth of prices. When combined with the objective of maintaining inflation close to 2%, that definition is likely to have fuelled the aforementioned perceptions of asymmetry, which may have hampered the anchoring of inflation expectations in recent years (Paloviita, Haavio, Jalasjoki and Kilponen, 2017; Hartmann and Smets, 2018).

The new strategy does not include a definition of price stability and sets out precisely the ECB's inflation target (Paragraph 5 of the Statement), which is its main feature of adaptation.

> The Governing Council considers that price stability is best maintained by aiming for two per cent inflation over the medium term. The Governing Council's commitment to this target is symmetric. Symmetry means that the Governing Council considers negative and positive deviations from this target as equally undesirable. The two per cent inflation target provides a clear anchor for inflation expectations, which is essential for maintaining price stability.
>
> Paragraph 5 of the Statement

The clear definition of the inflation target and the commitment to symmetry are therefore an important step, making it easier to effectively communicate the main monetary policy objective, which could contribute to a better anchoring of inflation expectations (Beechey and Österholm, 2018; Mishkin, 2008).

The choice of 2% for the inflation target thus ensures a good balance between obtaining some additional room for a decrease in nominal interest rates and mitigating the costs of too high a level of inflation, including its distortive impact (Adão, 2019).

Effective lower bound on interest rates

In its new monetary policy strategy, the ECB recognises that it can be challenging to maintain the symmetry of the inflation target when nominal interest rates are closer to the ELB (Paragraph 6 of the Statement).

> To maintain the symmetry of its inflation target, the Governing Council recognises the importance of taking into account the implications of the effective lower bound. In particular, when the economy is close to the lower bound, this requires especially forceful or persistent monetary policy measures to avoid negative deviations from the inflation target becoming entrenched. This may also imply a transitory period in which inflation is moderately above target.
>
> Paragraph 6 of the Statement

When policy interest rates come closer to the ELB (characterised by slightly negative interest rates), the room for additional accommodation is reduced. In this context, a possible fall in inflation cannot be countered by considerable cuts in interest rates, which may make it more difficult to prevent a prolonged period of low inflation. Against this background, economic agents' inflation expectations could decrease. This downgrade of inflation expectations may, in turn, make it difficult for actual inflation to rise again and approach the target.

To break this vicious circle, the ECB commits to implement forceful or persistent policy measures when the economy is close to the ELB on interest rates. This has already been done in the recent past through a set of non-standard monetary policy tools. It is acknowledged that this strong monetary policy impulse could push inflation above the ECB's target and it is further stressed that, albeit not an objective, this positive deviation will be tolerated if it is moderate and transitory. This tolerance for positive deviations from the inflation target is intended to ensure agents that there will not be a premature withdrawal of stimuli.

The ECB's approach should not be mistaken for distinct strategies that have been discussed in the literature and by central banks as solutions to overcome the restrictions imposed by the ELB on interest rates. Examples of these alternative strategies are price level targeting and average inflation targeting, implying that a period in which inflation has been below (above) the target should be proactively compensated by the central bank, in an effort to maintain inflation above (below) the target for a given period in the future. Thus, the price level does not deviate in the medium and long term from the level that would prevail if the central bank's inflation target were met at all periods. In August 2020, the US Federal Reserve adopted a strategy of average inflation targeting, albeit with several flexibility elements. In a context where economic agents can anticipate, understand and believe that the central bank will be able to meet this commitment without deviations, these strategies could mitigate the constraints imposed by the ELB and foster macroeconomic stabilisation. However, given the assumptions underlying these results, adopting this type of strategy may be ill-advised.[8]

Instruments

The new strategy acknowledges that the primary monetary policy instrument is the set of ECB policy rates. However, it is also noted that should interest rates come closer to the ELB other instruments may be employed, such as forward guidance, asset purchases and longer-term refinancing operations.

The explicit reference to additional monetary policy instruments is very relevant as it allows for a more foreseeable and agile application of these instruments, as appropriate. This reference enshrines the policy followed over the past few years. When nominal interest rates in the euro area approached the ELB, the use of non-standard instruments effectively helped establish the desired monetary policy orientation – see Altavilla, Burlon, Giannetti and Holton (2019) in the case of negative interest rates, Rostagno et al. (2019) on forward guidance, Andrade, Breckenfelder, De Fiore, Karadi and Tristani (2016) on purchases of public and private debt, and Andreeva and García-Posada (2021) on credit support tools. Asset purchases and credit support tools also helped safeguard an appropriate monetary policy transmission.

Finally, by stating that the selection or introduction of instruments will be flexible, in view of the challenges to be faced, the new strategy makes it possible to accommodate the potential complementarity between instruments, as well as the possibility of each instrument being more effective in addressing a specific challenge, or serving several objectives simultaneously. By communicating flexibility as a broad principle guiding the use of monetary policy instruments, the new strategy also provides clarity.

8. See Section 4.1 in Abreu and Valle e Azevedo (Eds.), 2021.

Economic analysis and monetary and financial analysis

As already mentioned, one of the core elements of the ECB's initial strategy, announced in 1998, was the comprehensive assessment of risks to price stability, but with a key emphasis on the analysis of developments in monetary aggregates. Since the 2003 strategy review, monetary policy decisions have been mainly driven by the economic analysis, but the monetary analysis has been enriched, with a greater focus on credit, the role of financial intermediation, asset prices and risks to financial stability.

The new monetary policy strategy reaffirms the importance of the economic analysis and, acknowledging the changing focus of the monetary analysis, refers to it as monetary and financial analysis (Paragraph 9 of the Statement). It is also recognised that the boundary between the economic and monetary analyses has become increasingly blurred as the interplay between financial and real dynamics becomes stronger. The recognition of these interdependencies makes it more relevant to assess the proportionality of monetary policy decisions and their potential side effects, and all these elements gain relevance in the new strategy.

The new strategy also stresses that the proper transmission of monetary policy requires careful monitoring and that financial stability, in a broad sense, is a precondition for price stability. These developments fully confirm the crucial role played by central banks in containing financial crises, which in the recent past translated into provision of ample liquidity to offset the collapse of private liquidity, including through purchases of assets that suddenly reached market valuations inconsistent with their intrinsic risk. The same rationale was followed during the pandemic crisis. Central banks' actions have been instrumental in safeguarding the functioning of markets, preserving the transmission mechanism, promoting favourable financing conditions and, as such, mitigating the effects of the pandemic. This focus on transmission is still particularly important in the current environment, as risks and vulnerabilities to monetary policy transmission have not fully dissipated and can be exposed again after the pandemic crisis.

> The Governing Council bases its monetary policy decisions, including the evaluation of the proportionality of its decisions and potential side effects, on an integrated assessment of all relevant factors. This assessment builds on two interdependent analyses: the economic analysis and the monetary and financial analysis. Within this framework, the economic analysis focuses on real and nominal economic developments, whereas the monetary and financial analysis examines monetary and financial indicators, with a focus on the operation of the monetary transmission mechanism and the possible risks to medium-term price stability from financial imbalances and monetary factors. The pervasive role of macro-financial linkages in economic, monetary and financial developments requires that the interdependencies across the two analyses are fully incorporated. This framework reflects the changes that the ECB's economic analysis and monetary analysis have undergone since 2003, the importance of monitoring the transmission mechanism in calibrating monetary policy instruments and the recognition that financial stability is a precondition for price stability.
>
> Paragraph 9 of the Statement

Finally, the reference to monetary factors in identifying risks to price stability should be noted. This is adequately grounded on the undisputed premise that inflation is a monetary phenomenon, i.e. driven by the equilibrium between supply and demand for assets that play the role of money. In the context of a weaker link between inflation developments and those in monetary aggregates, the measurement of monetary factors may gain renewed relevance in the assessment of risks to price stability if it also incorporates the analysis of the long-term consistency of inflation, policy rates and the natural real interest rate (the rate that balances demand and supply for savings in the long term), the latter being typically deemed as independent of monetary policy. This analysis, warranted given well-established long-run relations between these variables, highlights again that inflation is a monetary phenomenon.

Climate change

The role of monetary policy in the context of climate change has gained importance in the new strategy (Paragraph 10 of the Statement), confirming the ECB's alignment with one of the EU's key objectives for the coming years. In response to the 2015 Paris Agreement, the EU set the objective of attaining carbon neutrality by 2050, which has motivated and will still require numerous economic policy measures whose effects are interlinked with and could be affected by monetary policy.

The ECB will contribute by providing a comprehensive climate-related action plan that will incorporate, for instance, climate factors in its risk assessment and in the analysis of monetary policy transmission. In addition, the action plan will also require adaptations to the monetary policy operational framework in relation to reporting requirements applicable to commercial banks, corporate sector asset purchases and collateral accepted in banks' refinancing operations, which may have to present a 'greener' profile.

> Climate change has profound implications for price stability through its impact on the structure and cyclical dynamics of the economy and the financial system. Addressing climate change is a global challenge and a policy priority for the EU. Within its mandate, the Governing Council is committed to ensuring that the Eurosystem fully takes into account, in line with the EU's climate goals and objectives, the implications of climate change and the carbon transition for monetary policy and central banking. Accordingly, the Governing Council has committed to an ambitious climate-related action plan. In addition to the comprehensive incorporation of climate factors in its monetary policy assessments, the Governing Council will adapt the design of its monetary policy operational framework in relation to disclosures, risk assessment, corporate sector asset purchases and the collateral framework.
>
> Paragraph 10 of the Statement

The impact of climate change on the economies is foreseen to be complex and long-lasting. It could lead to a drop in equilibrium real interest rates, increasing the likelihood of the economy coming closer to the ELB and remaining there for some time. The monetary policy transmission mechanism may also be affected by increased uncertainty and volatility resulting from environmental instability. Finally, supply shocks due to extreme weather events may become more recurrent. The ECB could only react emphatically to these concerns and duly examine this issue.

Communication

As regards communication, the new monetary policy strategy epitomises some of the developments observed in recent years. Following the global financial crisis, the ECB significantly adjusted its communication by disclosing more detailed information on economic projections and policy instruments, increasing the number of public addresses by members of the Executive Board, publishing the accounts of monetary policy meetings and reducing the frequency of monetary policy meetings and the *Economic Bulletin*, which helped to promote the effectiveness of the most important messages. The ECB also started exploring new formats and communication channels using social media to reach out to new, less specialised audiences. Recent crises have highlighted the role of communication as a monetary policy instrument. A notable example was the 2012 speech in which President Draghi pledged to do "whatever it takes" to preserve the euro (Draghi, 2012).

The new strategy follows on from these communication efforts through various qualitative adjustments that promote greater accessibility of information, a multi-layered approach – i.e. differentiated communication aimed at addressing different audiences, from the general public to the most specialised audiences – and a more intensive dialogue with stakeholders. For instance, the listening events between the Eurosystem and the public will be made a structural feature of communication. These opportunities for improvement became apparent after the identification of inaccurate public perceptions regarding the inflation objective and large gaps in the public's knowledge of the ECB's other objectives and attributions.

Finally, the communication of monetary policy decisions through the Monetary Policy Statement, the press conference, the *Economic Bulletin* and the monetary policy accounts will be adapted to reflect the revised monetary policy strategy.

Regular monetary policy strategy review

The new strategy states the ECB's intention to conduct its review on a regular basis, indicating that the next review is scheduled for 2025. The desire to react more frequently to the rapid pace of change that has characterised the environment around monetary policy is therefore latent.

Concluding remarks

The review of the ECB's monetary policy strategy informs and should encourage the debate on the deepening of the EMU. The euro and its monetary policy have faced enormous challenges since its launch, largely resulting from the incompleteness of the EMU. In dealing with this framework, the ECB has on some occasions approached the boundaries of its mandate, with the aim of contributing to the stabilisation of the euro area. In a sense, the strategy review process itself enshrines the idea that the ECB's role has evolved significantly, partly as a response to the remaining room for deepening the institutional framework of the EMU. Although important steps have been taken in this deepening, in particular in the banking union and more generally in risk-sharing within the EU, this is a path that still needs to be pursued.

References

Abreu, I. and Valle e Azevedo, J. (Eds.) (2021). "Perspectives on the ECB's monetary policy strategy review", Lisbon: Banco de Portugal.

Adão, B. (2019). "Why is price stability a key goal of central banks?", *Banco de Portugal Economic Studies*, V(1), 67-87.

Altavilla, C., Burlon, L., Giannetti, M., and Holton, S. (2019). "Is there a zero lower bound? The effects of negative policy rates on banks and firms", *Working Paper Series*, No 2289, ECB.

Andrade, P., Breckenfelder, J., De Fiore, F., Karadi, P., and Tristani, O. (2016). "The ECB's asset purchase programme: an early assessment", *Working Paper Series*, No 1956, ECB.

Andrade, P., Galí, J., Le Bihan, H., and Matheron, J. (2019). "The optimal inflation target and the natural rate of interest", *Federal Reserve Bank of Boston Working Papers*, No 19-18.

Andreeva, D. C., and García-Posada, M. (2021). "The impact of the ECB's targeted long-term refinancing operations on banks' lending policies: the role of competition", *Journal of Banking and Finance*, 122, 105992.

Ball, L. (2014). "The case for a long-run inflation target of four percent", *IMF Working Papers*, No 14/92.

Banco de Portugal (2020). "The European Central Bank's monetary policy strategy: reasons for a review", Special issue, *Economic Bulleti*n, June.

Beechey, M., and Österholm, P. (2018). "Point versus band targets for inflation", *Örebro University School of Business Working Papers*, No 8/2018.

Brand, C., Bielecki, M., and Penalver, A. (2018). "The natural rate of interest: estimates, drivers, and challenges to monetary policy", *Occasional Paper Series*, No 217, ECB.

Draghi, M. (2012). Speech at the Global Investment Conference, London, 26 July.

Draghi, M. (2016). "Delivering a symmetric mandate with asymmetric tools: monetary policy in a context of low interest rates", speech at the 200th anniversary ceremony of the Oesterreichische Nationalbank, Vienna, 2 June.

ECB (2003). "Press seminar on the evaluation of the ECB's monetary policy strategy", 8 May.

ECB (2021). "ECB Listens – Summary report of the ECB Listens Portal responses".

Hartmann, P., and Smets, F. (2018). "The European Central Bank's monetary policy during its first 20 years", *Brookings Papers on Economic Activity*, Fall, 1-146.

Mishkin, F. S. (2008). "Comfort zones, schmumfort zones", speech at the Sandridge Lecture of the Virginia Association of Economists and the H. Parker Willis Lecture of Washington and Lee University, Lexington, Virginia, 27 March.

Paloviita, M., Haavio, M., Jalasjoki, P., and Kilponen, J. (2017). "What does 'below, but close to, two percent' mean? Assessing the ECB's reaction function with real time data", *Bank of Finland Research Discussion Papers*, No 29.

Rostagno, M., Altavilla, C., Carboni, G., Lemke, W., Motto, R., Saint Guilhem, A., and Yiangou, J. (2019). "A tale of two decades: the ECB's monetary policy at 20", *Working Paper Series*, No 2346, ECB.

Williams, J. C. (2009). "Heeding Daedalus: optimal inflation and the zero lower bound," *Brookings Papers on Economic Activity*, Fall, 1-49.

Climate change and the economy

Climate change has become one of the most important topics for public discussion in recent years. As this is a complex topic with many implications in a number of areas, it is necessary to choose the approach with which the problem is analysed; this Special issue provides an economic perspective. However, this requires understanding the causal links between the functioning of the Earth's climate system, the concentration of carbon in the atmosphere and economic activity. Appropriate economic policy measures to tackle climate change depend on these causal relationships. This Special issue analyses each of them with levels of detail calibrated for the reader interested in economic issues but not necessarily familiar with climate science. The Special issue has three sections: one focused on the analysis of global and Portuguese climate data; another by exploring the relationship between climate and economy and explaining appropriate economic policy interventions to mitigate the effects of climate change; and a third with a critical assessment of the economic impacts of climate change that can now be estimated. These sections are supplemented by three boxes. The first outlines the geophysical grounds of the greenhouse effect and global warming, focusing on the relationship between them and carbon dioxide emissions into the atmosphere. The second presents the implementation of an economic model as a means of assessing the effectiveness of different economic policy interventions in a world in energy transition. The third proposes a methodology for calculating the discount rate to be used in the assessment of long-term policies.

Climate data in Portugal and the world

This section presents some stylised facts on climate change for the whole of the Earth's surface and for mainland Portugal. It shows that global terrestrial temperature has risen by about 1 °C from the beginning of the twentieth century to today and that the increase has been geographically heterogeneous, with some areas heating more than others. For Portugal during the same period, average temperature increases were observed in almost the whole mainland, with significant spatial variation. The average annual rainfall has dropped in some areas of mainland Portugal, although in the territory as a whole the variation in rainfall during this period was not statistically significant. Box 1 presents, in plain language, the mechanisms by which the burning of fossil fuels caused by human activity and the consequent accumulation of carbon dioxide and other gases in the atmosphere leads to a warming of the global temperature of the planet.

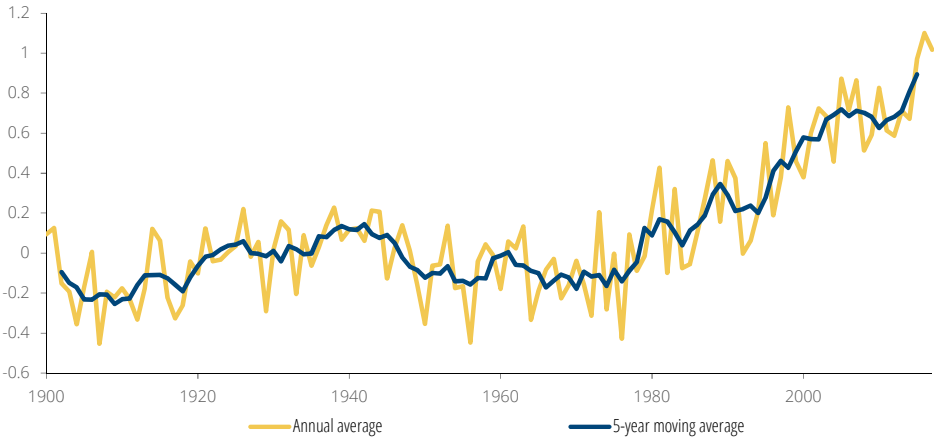
Changes in temperature and precipitation since the beginning of the twentieth century

The data used are publicly available from the University of Delaware (Matsuura and Willmott 2018a,b) on a monthly basis between 1900 and 2017, with a half-degree spatial resolution in longitude and latitude. In mainland Portugal this coverage corresponds to 40 locations. These data are complemented by the daily information from the E-OBS (Haylock et al. 2008, Cornes et al. 2018), publicly available for the period 1950-2020 and with a 0.1 degree resolution in longitude and latitude.

Chart 1 shows the evolution of the average annual temperature over the whole of the Earth's surface during the period 1900-2017, presented as the anomaly against the 20th century average. At the end of the period, the anomaly is about 1 °C. This increase is mainly observed in the second half of the twentieth century and up to 2017. Although the annual global average temperature

shows some volatility, the increase since 1950 of 0.17 °C per decade is statistically significant. These results do not differ substantially from the conclusions summed up in IPCC (2021), which put the anomaly, when compared with the pre-industrial period due to anthropogenic causes in the 2010s, in the range of 0.8-1.3 °C.

Chart 1 • Global Earth temperature | Anomaly compared to the 20th century average, in degrees Celsius



Sources: Matsuura and Willmott (2018a) and Banco de Portugal calculations. | Notes: The annual average temperature is defined as the average over the year of the monthly average temperature. Values are weighted by the respective geographic cell area.

Chart 2 shows the mean annual temperature change over the period 1950-2017, providing a spatial overview of this temperature increase. It is clear that almost the entire Earth's surface has heated up during the 68 years of this analysis. The calculated increase is statistically significant for 82% of the Earth's surface (at a 5% significance level), and contrasts with 2.8% of the Earth's surface area with a drop in average temperature. This chart evidences the global nature of the problem and at the same time its geographical heterogeneity. Secular temperature increase over almost the entire Earth's surface increases the frequency or severity of heat waves and reduces the frequency or severity of cold waves.

Greenhouse gas (GHG) emissions from anywhere on the planet will affect their concentration in the entire atmosphere and not just in the area close to the emission source. This makes the problem special from an economic perspective, meaning that we are facing a global externality: the GHG emitter subjects all other economic agents to its effects without incurring the full costs of its activity. This has far-reaching implications for the appropriate economic policies to tackle it, as seen in the following two sections.

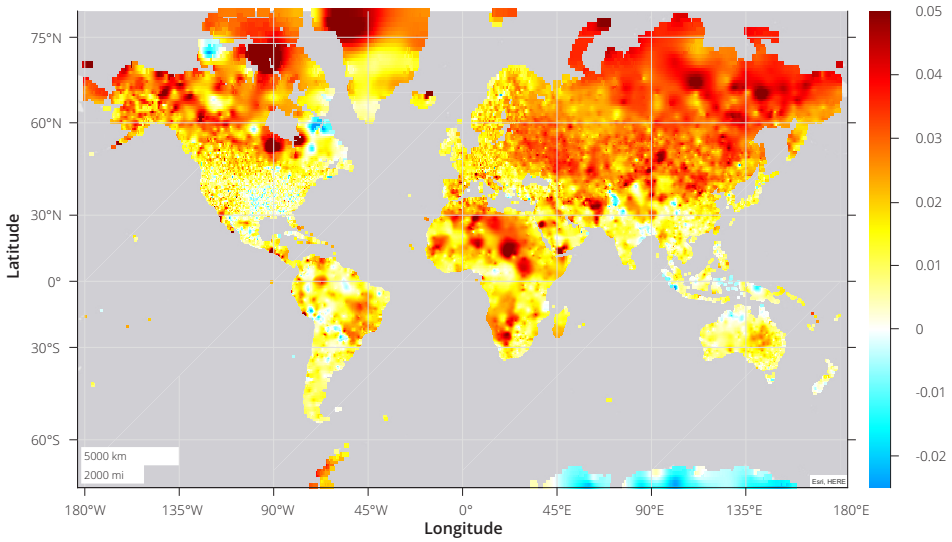
The overall amount of rainfall is likely to have increased as the climate has become warmer (IPCC 2021, p. SPM-6). This meteorological magnitude is harder to measure at a global level because it tends to be a localised phenomenon at each time. Moreover, rainfall over the oceans is unevenly measured. Concomitantly, recent literature reports an increase in the frequency of drought episodes in various regions of the world (IPCC 2021, p. SPM-12, and Páscoa et al. 2021).

In the Portuguese case, the average annual temperature during the 1900-2017 period also had a warming trend, but less pronounced than for the entire Earth's surface, with an anomaly of 0.6 °C compared to the 20th century average (Chart 3). The temperature increase from 1950 onwards was on average 0.077 °C per decade. Given the small size of the territory and its proximity to the ocean, the average annual temperature exhibits a more volatile behaviour for Portugal than for the entire

Earth's surface: the standard deviation over time is about 0.48 °C for Portugal against 0.34 °C for the entire Earth's surface.

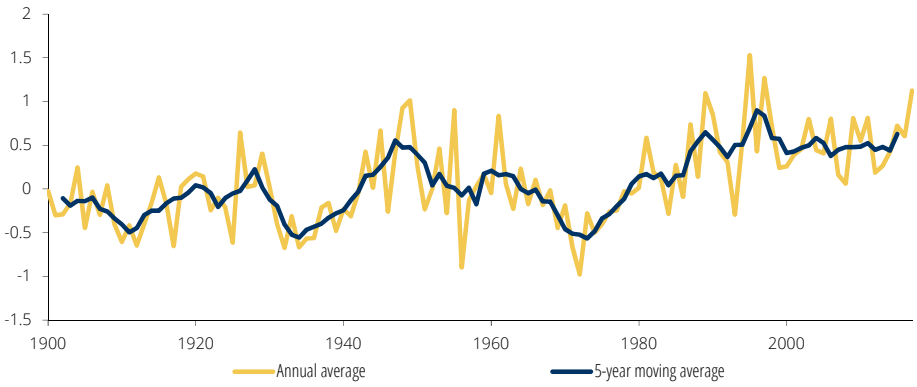
The trend observed for total annual rainfall is statistically zero in the period 1900-2017 (Chart 4). The annual rainfall variability in Portugal is extremely high, with a standard deviation of 193 mm around a mean of 849 mm.

Chart 2 • Average annual temperature change on the Earth's surface for the period 1950-2017 | Values in °C per year



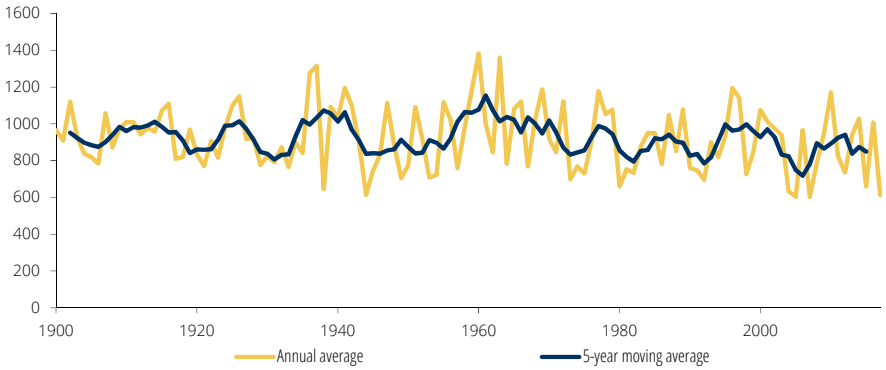
Sources: Matsuura and Willmott (2018a) and Banco de Portugal calculations. | Notes: The values represented correspond to the slope for each geographic location of the average annual temperature regression lines in the temporal variable (year). The average annual temperature is defined as the year-round average of the daily average temperature. Values truncated from above at 0.05 °C.

Chart 3 • Temperature in Portugal | Anomaly compared to the 20th century average, in degrees Celsius



Sources: Matsuura and Willmott (2018a) and Banco de Portugal calculations. | Notes: The annual average temperature is defined as the average over the year of the monthly average temperature. Values are weighted by the respective geographic cell area.

Chart 4 • Average annual precipitation in mainland Portugal for the period 1900-2017 | In mm

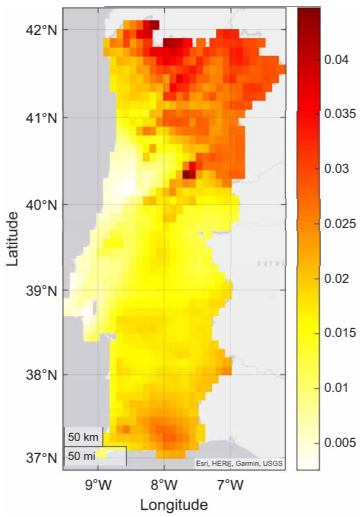


Sources: Matsuura and Willmott (2018b) and Banco de Portugal calculations. | Notes: Average annual precipitation is defined as the average for all geographic units of the cumulative precipitation value throughout the year. Values are weighted by the geographic area of the respective cell.

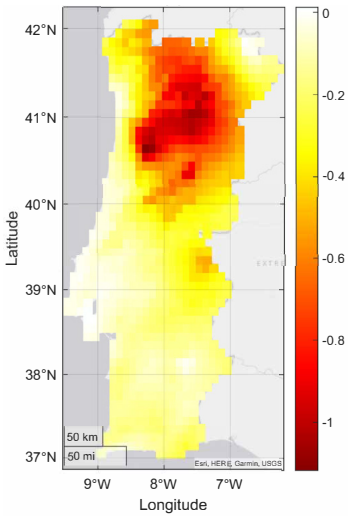
This scenario masks spatial variability within the Portuguese territory. The average annual temperature variation over the period 1950-2020 shows a broad-based increase across almost all regions but appears to be greater in the north-east of the country and in the Algarve (Chart 5 – Panel A). The estimated rate of heating[1] for these regions is sometimes higher than 0.4 °C per decade. These estimates show that some regions may be much more affected by climate change than others.

Chart 5 • Average annual change in temperature and precipitation in mainland Portugal for the period 1950-2020

Panel A – Average annual change in average temperature, in °C per year



Panel B – Average percentage change of total annual precipitation, in annual percentage



Sources: E-OBS and Banco de Portugal calculations. | Notes: The values indicated correspond to the slope for each geographic location of the regression lines of the dependent variable (average annual temperature or natural logarithm of the total annual precipitation multiplied by 100) in the temporal variable (year). The annual average temperature is defined as the year-round average of the daily average temperature. The total annual precipitation is defined as the year-round cumulative value of daily precipitation.

1. The estimated linear trends are sensitive to changes in the period under review and to the use of alternative databases, but the main findings do not change.

As for rainfall (Chart 5 – Panel B), the northern hinterland shows a significant reduction in the period 1950-2020. Even though the starting point in this region is high rainfall, in some cases there has been a 1% reduction per year, a figure that corresponds to an annual drop of about 15 mm in total rainfall. By contrast, the coast and the south of the country were largely resistant to decreasing rainfall.

Climate change is not limited to changes in variables such as average temperature or total precipitation. Just as important as the amount of rainfall over a year is its distribution along it and the prevailing temperature conditions. For instance, Páscoa et al. (2021) document a pattern of more prolonged and less intense droughts over the Iberian Peninsula in the period 1971-2015. This results not only from the downward trend in precipitation in some locations, but also from the increased intensity of evapotranspiration resulting from the secular rise in temperature.

Implications for energy consumption

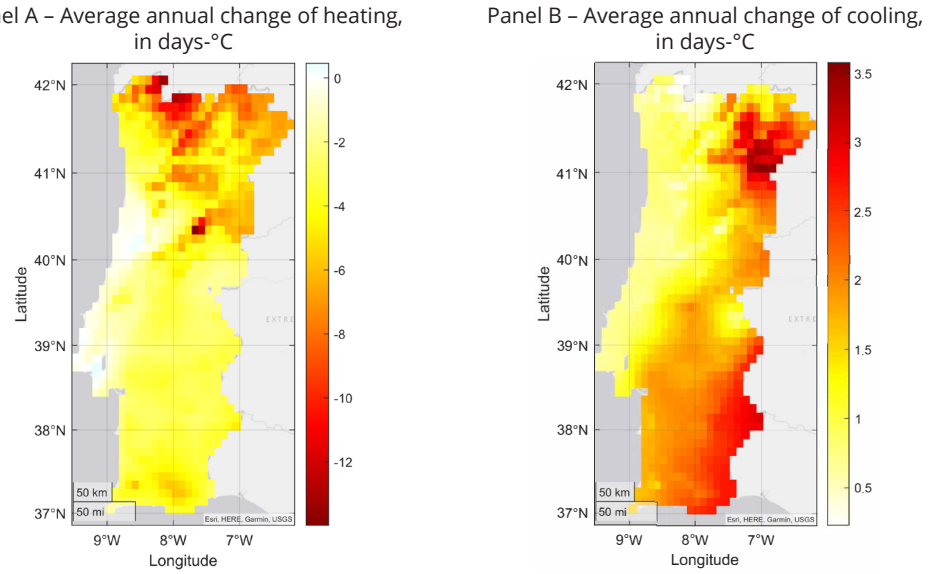
One of the economically relevant aspects of temperature change concerns energy consumption for both heating and cooling of buildings. Two standardised indicators published by official bodies are the heating or cooling degree Celsius days. They intuitively give us a measure of the heating or cooling needs of buildings to remain at comfortable temperatures throughout the year.[2] Each additional degree Celsius-day heating means that the temperature needs to be raised by 1 °C for one day, or 0.5 °C for two days, and so on. The energy expenditure associated with these needs obviously varies with building characteristics: if the thermal insulation of buildings improves over time, the energy required for the same level of heating or cooling of a building will be lower.

In Portugal, over the period 1950-2020 the heating needs dropped by 3.7 days-°C per year. This development will, in principle, lead to energy savings, but it conceals great variability in the Portuguese territory. It is especially in the north that it has become less necessary to heat buildings (Chart 6 – Panel A), which will lead to less energy needs. Using Eurostat data for the period 1979-2020, the reduction was about 5.3 days-°C per year, a smaller figure than for all EU countries, with a reduction of 14 days-°C per year.

The annual change in cooling needs over the same period increased across the country's internal band (Chart 6 – Panel B), representing increased energy expenditure. The average figure for the entire mainland Portugal was 1.6 days-°C per year. For the period 1979-2020 and using Eurostat data, the increase in cooling needs was 1.2 days-°C per year, lower than for all EU countries (1.6 days-°C per year).

2. For definitions of these indicators, see https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Heating_and_cooling_degree_days_-_statistics.

Chart 6 • Average annual change of heating and cooling energy indices in mainland Portugal for the period 1950-2020



Sources: E-OBS and Banco de Portugal calculations. | Note: Values computed according to the Eurostat methodology.

Facts to be retained

Some key ideas are drawn from this section and Box 1. First, during the twentieth century and so far there are significant changes in important climate variables such as average temperature and total annual precipitation. These changes lead to a secular increase in the Earth's surface temperature, an increase in overall annual rainfall and an increase in the frequency of extreme events. Second, changes in the most important climate variables are geographically very heterogeneous, even within relatively small geographical units such as mainland Portugal and will also have differentiated and difficult to assess economic consequences. Third, as described in Box 1, there is a well-known causal mechanism associated with human activity and resulting GHG emissions, which, due to the particular thermodynamics of the Earth-atmosphere system, leads with great certainty to a progressive warming of the atmosphere. Finally, while there have always been changes to the Earth's climate systems, these are now measurable and verifiable on a much shorter time scale than in the past.

The economy in a world with climate change

Energy consumption by burning fossil fuels leads to an accumulation of GHG, and in particular CO_2, in the atmosphere. Energy is needed for virtually all economic activities, which are therefore highly relevant for the climate. The other sense of implication – that the climate affects economic activity – is perhaps less exploited, but no less obvious.

From an economic perspective, GHG accumulation corresponds to an overall negative externality: those who produce carbon dioxide emissions do not pay their full cost, since society as a whole is not compensated. As the private cost of production is lower than the social cost, the production of carbon-intensive goods and services is excessive compared to what would be socially desirable. In the presence of externalities, the free functioning of the market does not lead to efficient results. In general, appropriate public policies can address, or at least mitigate, externality effects.

Interaction mechanisms between the macroeconomy and climate

The impact of climate change on the economy is usually done by assessing each sector of activity, with subsequent aggregation, where possible taking into account interlinkages between sectors and energy costs such as those seen in the previous section. Economic agents, in turn, react to these factors and affect them. Despite the high inaccuracy of estimates, several transmission channels have been identified in the economic literature.

- Price and income volatility

Extreme weather events can be understood as negative supply-side shocks with price spillovers. Such shocks may lead to an increase in inflation in developing countries in the short term, which may become persistent (Parker 2018). The distortion of relative prices of food or raw materials may affect the general price level in economies most exposed to the primary sector. An important transmission channel is energy, as firms in energy-intensive sectors will be more vulnerable to energy price fluctuations.

The effect of rising temperatures on income volatility has also been documented. For example, Deryugina and Hsiang (2014) study the impact of daily temperature variations over a 40-year period on US counties, showing a negative effect of temperature on productivity and income above a certain threshold.

- International trade flows

The impact of extreme events on international trade is well documented in the literature (Gassebner, Keck and Teh 2010, Oh and Reuveny 2010). The severity of the effects will depend on the degree of integration of economies into global value chains, so even economies that are little exposed to extreme events will be affected by developments in trading partners. This could lead to a relocation of firms to less affected regions, resulting in a transfer of capital stock, employment and production across countries, a phenomenon with wide-ranging socio-economic implications.

- Capital stock reduction

The destruction of infrastructure, transport networks, energy and water supply by climate factors (mismatch with new climate conditions, extreme events, rising sea levels, etc.) can greatly reduce the capital stock of the economy, resulting in losses in labour productivity and attractiveness of productive investment. For example, Fankhauser and Tol (2005) show that the frequency of extreme events affects the lifetime of physical capital. Concomitantly, there will be an increase in resources dedicated to adaptation, such as spending on energy efficiency of buildings or infrastructure to mitigate sea level rise.

The consequences for the insurance sector should not be neglected. The increased frequency of extreme events may lead to certain types of risks becoming too expensive to be insured; one example is the existence of dwellings in areas vulnerable to floods. Exposure to high or uninsurable risks on the market may lead to the need for firms and households to increase their precautionary savings.

- Obsolescence of assets

The transition to a low-carbon economy leads to the abandonment of some current technologies, leading to assets in certain industries becoming stranded, with direct consequences for employment. The level of losses generated will depend on the degree of country exposure to such assets or the adoption rate of alternative technologies. Cavalcanti, Hasna and Santos (2021) show that the costs of an energy transition will be higher for skilled workers in more energy-intensive sectors of energy polluting technologies, and consequently for the most relevant countries in these sectors.

- Migration

Labour mobility can increase as a result of climate change (Rigaud et al. 2018). This phenomenon influences migration decisions through the usual determinants, in particular economic (e.g., through lower real wages in rural areas), environmental and, to a large extent, political factors. Cattaneo and Peri (2016) conclude that rising temperatures and natural disasters lead to emigration in developing countries, except for those with lower income levels, where populations cannot relocate.

- Other factors

Climate change can cause losses in GDP typically unrecorded, such as health risks, disruption in communities forced to relocate and biodiversity loss or environmental quality. This consideration suggests complementing GDP with satellite accounts measuring environmental and social variables affecting well-being. This will possibly be a necessary methodological development in the coming years.

Economic policies to mitigate the effects of carbon emissions

To the extent that fossil fuel emissions exert negative externalities on economic agents, it is desirable to consider policies aimed at mitigating their effects and increasing the well-being of economic agents. This section addresses this issue from two perspectives: the general economic policies appropriate to the problem, and the specifics regarding the financial system and central banks.

- Carbon taxes and tradable emission permits

The most cited intervention to effectively tackle the problem of climate change is to put a price on carbon and other GHG emissions. The higher the amount to be paid for GHG emissions, the lower the number of emissions. By having to pay for carbon emissions, economic agents are encouraged to cut them by reducing GHG-generating activities and innovating to limit the dependence of economic activity on fossil energy sources. For a given aggregate reduction in GHG emissions, the total costs borne by society in implementing a tax solution will be lower than those incurred by direct regulation of economic activities, commonly referred to as "command and control".

There are at least two alternative mechanisms for putting a price on carbon. The first mechanism is the introduction of corrective taxes, the so-called Pigou taxes: goods and services are subject to (additional) taxes the value of which depends on the amount of carbon emitted in their production and distribution. One example is the cost of a litre of fuel to include a tax corresponding to the associated carbon emission. The exercise presented in Box 2 is based on such a policy.

In the second mechanism, instead of fixing a price, an aggregate amount of carbon emissions is set, corresponding to a given amount of tradable carbon permits, an approach proposed by several authors, inspired by Ronald Coase's analysis of externalities and the specification of property rights. The purchase of one of these permits grants the right to emit a carbon unit. The most relevant mechanism of this type is the European *Emissions Trading System* (ETS), where the base unit is the tonne of CO_2. The emissions permit scheme is known as cap and trade: the authorities define a total number of permits (cap), which can be bought and sold by economic agents (trade).

In the presence of uncertainty, there are some differences between the two mechanisms, theoretically translated, in the case of Pigou taxes, into greater volatility of carbon emissions and, in the case of emission permits, greater volatility of permit prices. Which system is the most cost-effective? The response depends on the sensitivity of environmental costs and the costs of reducing emissions relative to the number of emissions. By adapting Weitzman's (1974) traditional analysis to the issue of taxes versus permits, it is clear that if environmental costs are more sensitive to the number of emissions than the costs of reducing emissions, it is preferable to reduce uncertainty in the number of emissions, which points to an emission permit mechanism. Otherwise, it is preferable to reduce uncertainty in emissions, which points to the superiority of a carbon tax scheme (Adar and Griffin 1976).

There are arguments in favour of either mechanism. To the extent that environmental costs depend on the GHG stock and not on the emissions of a particular year, the previous rule would imply a superiority of the taxation scheme. Secondly, it is common ground that a tax scheme has fewer administrative costs and less complexity than an emission permit scheme when taking into account the costs of starting up and managing the distribution of permits and their monitoring. Moreover, many countries already have structures in place that administer fuel taxation. Thirdly, uncompetitive behaviour and market manipulation may weaken the ability of the emission permit scheme to achieve efficient control of global GHG emissions. Finally, the tax mechanism has less incompatibilities when considering interactions with complementary interventions, such as the implementation of fuel standards, or favouring "green" investments in financial markets.

In favour of the emission permit scheme, Stavins (1996) argues that the correlation between fluctuations in emission reduction costs and environmental costs implies that the emission permit scheme is superior. It is also argued that the emission permit scheme is adapted more quickly and flexibly to changes in emission reduction costs, which might require changes in taxes that are more difficult and slower to materialise. In addition, the possibility of saving permits acquired for use in subsequent periods (the so-called banking) or the creation of price stability buffers (as in the case of European ETS) make it possible to mitigate the problems of price volatility of this scheme. Moreover, minimum or maximum limits may be imposed on permit prices. In practice, most current ETS have adopted PSAM (Price or Supply Adjustment Mechanisms) to reduce (positive or negative) peak permit prices.

The inclination of interest groups or sectors of economic activity to achieve special tax treatment shows that carbon taxes may, in practice, not fully achieve their objectives. This is exemplified by the use of GHG-generating fuels that are not covered by emissions licenses and sometimes are even subsidised. Another problem is that such economic policies require international cooperation, in particular among the largest emitters (e.g., China, the US, the European Union and India). It is often argued that a country alone cannot solve the problem. In a non-cooperative economic equilibrium, each country will expect others to bear the necessary costs, and none will end up incurring those costs. This makes it difficult to sustain carbon tax policies adopted by all countries.

Choices on the allocation of revenues from carbon mitigation policies can contribute to a better public acceptance of these policies. For example, rebating such revenues to consumers changes the incentives for those who are most affected by rising energy costs in general.

Another area where taxes are presented as necessary instruments is border adjustments, taxing imports from producers who do not bear reasonable carbon costs. An alternative to border adjustments would be a more downstream taxation in economic circuits, for example on the use and consumption of imported goods by end consumers.

Two conclusions have been drawn from these considerations. One is that the details of the implementation of the carbon tax or emission permits are potentially more important than the conceptual differences between the two mechanisms. The second conclusion is that the best way to impose carbon prices requires a system with the simultaneous use of emission permits and carbon taxes. This hybrid system corresponds to the situation in the European Union. The European ETS covers only part of the economic activities, in particular sectors such as power generation, foundries, cellulose, cement plants and, more recently, aviation. In general, only large enterprises are part of the ETS. In many European countries carbon taxes are imposed on economic activities not covered by ETS, including land transport.

Despite the existence of ETS and the application of carbon tax in several regions of the world, the overall share of CO_2 emissions that pay a price is still low. Prices charged are very heterogeneous across countries. Actual prices, weighted by coverage rates, are low compared to what is necessary to limit the global temperature increase to 2 °C.[3]

According to current estimates (World Bank 2021), only 21.5% of global emissions are covered by ETS or carbon taxes. The same source refers that only 3.76% of global emissions pay a carbon price above $40 per tonne of CO_2.

There is a wide heterogeneity across countries. According to the World Bank, Portugal will have around 29% of its CO_2 emissions covered by carbon taxes in 2021, which is lower than that of the Scandinavian countries (Norway 66%, Sweden 40%), but higher than that of other EU countries (Poland 4%, Spain 3%). In turn, the European ETS covers around 39% of emissions in the European Union.

- Implications for the financial system

Complementing fiscal measures, the role of the financial system in reducing GHG emissions has been recognised, given its key role in resource allocation in the economy. Measures related to the financial system may, in principle, result in a better overall policy mix, given the uncertainty about the assumptions determining the design of tax measures, and political economy issues relating to the nominal incidence of taxes and their redistributive effects, which may justify a greater role assigned to other policies.

From an economic perspective, the first step in the analysis of measures targeting the financial system should be to identify market failures to which they can respond. In this context, the market failures commonly pointed out result from:

– shortcomings in reporting on the environmental effects of certain industries or firms and their susceptibility to climate change, which may give rise to little recognition of the associated risk;

3. https//bcf.princeton.edu/events/williamnordhaus.

– externalities of certain activities, which will be negative in the case of GHG emissions that are too high compared to what would be socially desirable, and positive in the case of too low investment in the development and adoption of renewable energy technologies, characterised by gains in mass production or network effects.

The first shortcoming can be addressed with additional disclosure of information; the latter can be resolved by fiscal or equivalent measures.

- Reporting and financial regulation

The lack of granular, forward-looking and verifiable environmental information persists, especially in small-sized enterprises. Measures framing the regulation and supervision of the financial system aimed at ensuring credible and comparable information, standardised disclosure of environmental data by firms and correspondence with a globally accepted taxonomy would contribute to a better assessment of climate risks and the environmental impact of firms by consumers and investors. This guidance can be strengthened through the role of central banks as monetary authorities – i.e., even when they are not supervisors – as the design of monetary policy (e.g., corporate bond purchase programmes) can be made conditional on reporting requirements by banks and firms that finance themselves on the capital market.

Proposals have also been made to give more favourable regulatory treatment, in terms of capital and other requirements, to green credit, or credit to firms or projects that are so classified. However, the purpose of capital requirements is to ensure that banks can absorb losses. Assuming adequate environmental reporting by firms and banks, the risk assessment of green projects should not be systematically biased compared to that of other projects. In fact, a regulatory treatment going beyond risk considerations subsumes a subsidy for green activities. Even if justified, implementation difficulties and efficiency issues exist. A more favourable regime for green firms or projects creates incentives for regulatory arbitrage, which in this case will try to classify projects or firms as green or seek more favourable jurisdictions. Another issue is to ensure that a given financing is earmarked for a specific purpose within a firm or corporate group, which can be channelled to less green (or even external) group firms, contrary to the objective of the measures.

- Monetary policy

Central banks also play a role in the possible subsidising of green activities by buying green bonds or, in the context of refinancing operations to banks, in the favourable treatment of green loans given as collateral through smaller haircuts, for example. This could result, in particular, in subsidising renewable energy production. However, Hassler et al. (2020) suggest that the use of green energy subsidies leads to higher total energy consumption, with limited effects on mitigating global temperature increase. One such policy is simulated in Box 2, showing that its impact, although not negligible, is smaller than carbon taxation.

In the case of monetary policy refinancing operations, if the concerns are purely risk, it does not seem necessary to split credit into green and non-green; it will be sufficient to measure the additional risk imposed by climate change on firms and to incorporate it into the collateral framework, as mentioned above. If the objective is to subsidise green credit, the main benefit results from more favourable conditions for the use of green credit portfolios as collateral in future refinancing operations. Typically, only in one-off (crisis) situations are these credit portfolios used in these operations.

Corporate bond asset purchase programmes are a recent tool with the specific aim of enhancing the accommodative character of monetary policy. Where these programmes did not exist,

monetary policy had a broad-based impact on the different segments of the financial markets, including financing to non-green firms. A policy of preferential green asset purchases could affect relative prices in these markets at the expense of non-green assets.

It is important to note that these programmes are designed to meet an inflation target (as is the case of the ECB) or macroeconomic stabilisation, ceasing when these targets are met. A future need for disinvestment in green assets could be interpreted as a devaluation of central banks' climate concerns, generating reputational costs or tensions with their mandates. The allocation of climate objectives to monetary policy, in a context where its ability to achieve them is limited, should take into account the independence of central banks, which is granted on condition that they operate within a limited area of competence.

This does not prevent central banks, as relevant organisations, from fulfilling sustainability and corporate responsibility criteria and taking initiatives that represent a valuable contribution to the mitigation of this overall problem. In the case of the Banco de Portugal, mention is made of its commitment to sustainability and sustainable finance, its participation in the Network for Greening the Financial System (NGFS) and the National Adaptation Roadmap 2100, and its participation in the Bank for International Settlements' green funds. The reader is also invited to refer to the documents already published from the recent review of the ECB's monetary policy strategy, which list the various ongoing and forthcoming initiatives.

- Other policies

A number of general and sectoral policies that seek to mitigate climate change, as well as those seeking to adapt existing production systems to it, are excluded from this analysis. Examples include incentives for research and development activities aimed at mitigating carbon emissions or adapting to their effects. The outcome of this type of initiative is uncertain, but the ingenuity and innovation capacity of scientists and entrepreneurs should not be underestimated. This category includes efforts to clean up energy production technologies, increasing the energy efficiency of production and transport processes, energy storage systems, atmospheric carbon sequestration technologies or processes, among other examples. The policy requirements described above and based on taxes or emission permits already provide incentives for this type of investment.

Estimates of the economic impact of climate change and its mitigation

This section provides estimates of the impact of climate change on the economy. It is necessary to place those estimates in the context of the uncertainty inherent in the exercise. Many of the climate consequences of an increase in temperature throughout the twenty-first century are unknown today. Another aspect is that, in our current assessment of which economic policy will optimise the welfare of people living or going to live in this century, we will have to use some discount factor for future generations (Box 3), and this will affect the characteristics of optimal mitigation policies.

Published credible estimates can be grouped into at least two non-mutually exclusive categories. The first category relies on *Integrated Assessment Models* (IAM) by using estimates of the impact of anthropogenic carbon emissions on the climate, and on the development of economic activities, obtained through statistical analysis and case studies. These components

are embedded in a formal equilibrium model in which households save, consume and invest by optimising their welfare, subject to quantitative constraints stemming from produced and extracted resources (goods, fossil fuels, solar energy, etc.), existing technologies, the structure of markets for productive factors and goods, price developments (including relative prices of different types of energy, wages and interest rates) and government policies. This macroeconomic approach can be found in other areas, such as assessing the welfare costs of economic fluctuations or financial crises and seeks to estimate an expected or more likely value for impacts.

The other category puts more emphasis on the negative risks to human welfare from climate change. This is a stress test approach aiming at answering the question: what economic costs due to climate change will economies bear in an unlikely but possible highly disruptive scenario? The methodologies used depart from the models described above but are then complemented by assessments of risk factors ignored or unknown from the initial analysis.

Economic literature

The economic literature distinguishes between two types of effects arising from climate change: direct and indirect. Direct effects mainly concern distortions of the normal functioning of the natural climate system which, as seen in the climate data section, lead to an increase in the Earth's average temperature, an increase in the average sea level and a higher frequency of extreme events. Indirect effects, in turn, result from the reaction of economic agents to the new climate conditions and mitigation efforts undertaken by governments and other agents, which typically entail a shift towards a low-carbon economy.

Tol (2018) reviews existing estimates in the literature of the economic impact of climate change for different temperature increases and the distribution of these impacts across the world (Table 1). At the same time, the author acknowledges that the literature does not incorporate some important elements (non-linearity of effects, currently unknown phenomena) and that the uncertainty surrounding estimates alone motivates the reduction of GHG emissions. In any case, values should be put in a context of expected value and compared with estimates applicable to other relevant economic phenomena. A discussion of this issue is presented in Box 2.

The impacts of climate change are more severe in developing countries, mainly due to the existing level of poverty. On the one hand, the exposure of these countries to climate conditions is greater due to the predominant role of agriculture and water resources in the economy. On the other hand, these countries are located in warmer places, making ecosystems closer to limits compatible with human habitability. The adaptability of these countries also tends to be more limited due to low levels of technology, per capita income and openness of their economies (Noy 2009).

Even in developed countries the economic impacts of climate change are very heterogeneous and entail a sharp increase in income inequality between countries and regions. For instance, Hsiang et al. (2017) estimate that while US GDP costs are 1.2% for each degree Celsius of average temperature warming, the effects are spread asymmetrically on US territory, with some regions losing 20% of output by 2100 in a scenario where current policies continue.

Table 1 • Impact of climate change in world GDP

Increase of the mean global surface temperature (ºC)	Number of estimates	Percent impact in GDP level	
		Average of estimates	Estimates range
≤ 2	4	0.3	-0.5 to 2.3
2.5	11	-1.3	-3.0 to 0.1
2.9	2	-2	-2.1 to -2
3	6	-1.7	-3.6 to -0.9
3.2	1	-5.1	-5.1
5.4	1	-6.1	-6.1
6	1	-6.7	-6.7

Source: Adapted from Tol (2018). | Note: Percent impact in GDP level in 2100 relative to a scenario without climate change.

Estimates in a stress test environment are higher, as would be expected. For example, a recently published report (Swiss Re Institute 2021) considers not only known channels of climate impact on the economy, but also unknown or not yet quantified channels. The methodology uses models developed by Moody's (2019) and applies a factor of one order of magnitude to the cumulative economic effects due to temperature increase. The costs of a carbon emission trajectory comparable to the IPCC (2021) SSP2-4.5 scenario[4] versus a world with no temperature increase could be of the order of 13.9% in 2050, corresponding to a temperature increase of 2.6 °C. This impact would mainly affect countries in South-east Asia such as Malaysia, the Philippines and Singapore, with falls of around 35%. Africa would also be severely affected. In Europe the falls would be 8%. These figures should be interpreted as possible, although not likely, effects and show how damaging climate change could be for the economy. In a somewhat less pessimistic note, this type of approach also tends to ignore positive technological developments in tackling this problem.

Two conclusions emerge from this discussion. First, the economic impacts of climate change can range from moderate to intense, depending on the trajectory of emissions, policies adopted, and phenomena not yet quantified or known. Second, costs are distributed in a heterogeneous way, with average effects masking values which, in practice and in some regions, mean an unprecedented economic decline.

4. The base scenario is the IPCC (2014) RCP4.5.

Final remarks

This Special issue addresses the problem of climate change and its interaction with the economy. Climate change, an old phenomenon, has become more intense through increasing GHG emissions from the mid-nineteenth century on, with the progressive industrialisation of economies. The scientific literature on the topic describes the main effects of this large accumulation of GHG in the atmosphere over the coming decades and centuries: increase in average temperature on the surface of the Earth, higher incidence of extreme weather events and a rise in the average sea level. These effects will be very diverse geographically. In Portugal, the rise in temperature has been lower than that observed throughout the planet due to its Atlantic location.

Climate change mitigation policies necessarily rely on reducing GHG emissions. Being a global negative externality, the best way to address it would be through a global GHG emissions tax, possibly coupled with other measures, including those relating to the shift to a less polluting technology-driven economy. The role of central banks is also analysed.

The impact of climate change is currently a very active topic of research and economic analysis. Available estimates, although surrounded by great uncertainty, point to impacts comparable to or greater than the effects of major economic phenomena studied for decades, such as inflation, unemployment and business cycles. There will also be strategies to adapt to changes that may limit the impacts in the long term. Given the high degree of uncertainty and the possibility of extreme events, there is an important role for their analysis in a precautionary approach. These are some of the reasons why economists will be increasingly involved in this topic.

Box 1 • Notions about the Earth's climate system

The natural climate system is incredibly complex. Describing it is a hard task and so scientists use models to try to understand their mechanisms, model them and quantify them. The Earth's climate is the result of many natural phenomena involving the atmosphere, the Earth's crust, the oceans, the cryosphere (i.e., the ice-bearing part of the Earth and sea), the biosphere, the inside of the Earth, the Sun and the Moon. Other important elements – for example cosmic radiation – could also be listed, but it is clear that modelling them all is impracticable and possibly unnecessary.

At first sight it is not evident that GHG emissions from fossil fuel combustion from human activities have a significant impact on the climate. Estimated carbon dioxide emissions (CO_2, the best-known GHG) for 2018 amount to about 37 gigatonnes ($GtCO_2$), which will correspond to some 4.7 parts per million (ppm).[5] The concentration of CO_2 in the atmosphere is currently around 410 ppm, or 0.041%. Although this represents a significant increase from the mid-nineteenth century level, when it was 285 ppm, how can such a residual fraction of the atmosphere have such a large impact on the natural climate system?

In order to answer this question, it is necessary to understand how the thermodynamics of bodies works, what are the energy exchanges between the Earth, the atmosphere and the outer space, and what the impact is of GHG on such energy transfers. See Rose (2021) for a detailed analysis of this topic.

Body thermodynamics

All bodies exchange energy, which tends to flow from warmer bodies to colder ones. The transfer of energy from a body to everything around it cools it, while heating the bodies and environment around it. How does this transfer of energy take place? In simple terms, a body radiates the more energy the warmer it is. Such radiation is done in a variety of ways, including heat and electromagnetic waves.

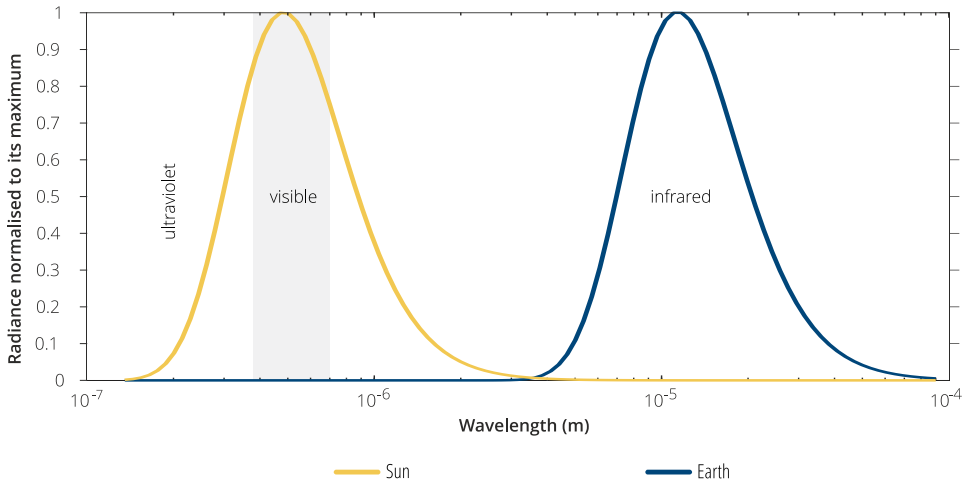
Bodies with temperature above absolute zero (0 degrees Kelvin[6], or -273 °C) radiate electromagnetic energy at various frequencies depending on their composition. At the same time, they also tend to reflect part of the electromagnetic radiation affecting them.

Energy exchanges between Earth, atmosphere and outer space

These principles apply to the Earth's system, its atmosphere and the outer space. The outer space contains a particular body, the Sun, which is a very powerful source of energy, flooding the Earth and its atmosphere with electromagnetic radiation. The heat of the Sun is the result of nuclear fusion reactions that occur constantly in its core, producing electromagnetic radiation in all directions. Part of this energy, in the form of visible light, ultraviolet radiation and infrared radiation, reaches the Earth and its atmosphere, which, as we have seen, will reflect part of that energy and absorb the rest. Chart C1.1 shows the magnitude of the Sun's radiation for various wavelengths (known as spectral radiance), normalised to its maximum value. The pattern observed is known as Planck's law. Note that the higher wavelengths of radiation correspond to lower frequencies. The radiation of the Sun is maximum in wavelengths visible to the human eye and a significant part of the total energy affecting the Earth (proportional to the grey area under the Sun curve) is visible light.

5. The units commonly used in the literature on carbon emissions are the gigatonne of carbon dioxide ($GtCO_2$), the gigatonne of carbon (GtC) and the part per million (ppm). One GtC corresponds to 3.664 $GtCO_2$ and one ppm corresponds to 7.782 $GtCO_2$.
6. Approximately Zero Kelvin degrees, denoted by 0 K, corresponds to -273 °C, and 273 K corresponds to 0 °C, approximately.

Chart C1.1 • Spectral radiance of the Sun and Earth



Source: Banco de Portugal calculations. | Note: Spectral radiance is calculated based on Planck's formula assuming that the temperature for the Sun is 6000 K. For Earth the value of 255 K was assumed, which corresponds to the temperature of the Earth-atmosphere system seen from outer space.

The atmosphere is almost transparent to solar radiation, which will heat the Earth's surface. Part of the solar radiation will be reflected by soils and oceans (in particular in areas covered with snow and ice) and clouds. The relationship between the energy reflected and the energy received by the Earth's surface and cloud cover is called the terrestrial albedo. In general, an object with an albedo close to 100% reflects almost all the light affecting it. A dark object tends to absorb light and should therefore have a low albedo. The terrestrial albedo averages around 30% per year.

If solar energy on the Earth is not compensated, the planet will heat up until it becomes uninhabitable. On the contrary, it is known that the Earth's temperature, although fluctuating very significantly over time, has not shown a permanent upward trend. The explanation for the apparent impossibility is the electromagnetic radiation which all bodies emit referred to above. The Earth emits electromagnetic radiation because its average surface temperature is higher (in fact, much higher) than absolute zero, and so is its atmosphere. Electromagnetic energy radiated by a body such as the Earth is well approximated by the energy emitted by a black body in thermodynamic equilibrium, which is an abstraction for a body that absorbs all the electromagnetic energy affecting it and radiates with the same intensity in all directions according to Planck's Law. The relationship between radiated energy and black body temperature is given by:

$$E = \sigma T^4 \tag{1}$$

where E is the radiated energy in watt per square metre ($\text{watt} \cdot \text{m}^{-2}$), T is the average temperature at the surface of the body in degrees Kelvin, and σ is the Stefan-Boltzmann constant, with a value of 5.67 x 10^{-8} (in $\text{watt} \cdot \text{m}^{-2} \cdot K^{-4}$). This non-linear and positive relationship between energy and temperature will be useful ahead.

The radiation of a body occurs at temperature-dependent wavelengths. In the case of the Earth-atmosphere system, the radiation is above the range visible to humans, and compensates for the energy reaching that system so as to maintain the temperature approximately constant. Chart C1.1 shows the intensity of this radiation at the various wavelengths. Note that the values are maximum at wavelengths well above those of solar radiation and that there is hardly any spectral overlap in

the radiation of the two bodies. In Chart C1.1, the spectral radiance of the Earth-atmosphere system is normalised to its maximum value, which is about 7.2 million times lower than that of the Sun. At the same time, only a small part of the energy radiated by it reaches the Earth and its atmosphere.

The atmosphere is a stand-alone component of the Earth's climate system. The gases of which it is composed (including several GHG) radiate energy, like any other body, especially in the infrared region. Part of this radiation dissipates in space (about 39% of the total) and the rest reaches the Earth's surface (about 61% of the total).

For the Earth's surface, in addition to the light reflected, most of the energy emitted is in the form of infrared electromagnetic radiation (about 80% of the total). A small part (about 5.5%) is released directly into space, the so-called "atmospheric window", with the remainder staying in the atmosphere. Other heat transfers from the Earth's surface to the atmosphere occur by evapotranspiration[7] , fires, volcanoes and other phenomena (about 20% of the total).

To get an idea of these magnitudes, the average annual energy intensity of the Sun incident on Earth and atmosphere, known as **insolation**, is 341.3 $\mathbf{watt \cdot m^{-2}}$. The total energy emitted by the atmosphere is 61.1% higher than this, while the energy emitted by the Earth's surface is 44.7% higher. It has already been noted that the atmosphere plays an important role in mediating the transfers of energy from the Sun to the Earth's surface and from the surface to the outer space.

This very peculiar energy balance gives rise to the notion of "greenhouse effect". The Earth emits energy in the form of infrared electromagnetic radiation according to expression (1) and wavelengths of Chart C1.1, but the electromagnetic energy that actually escapes into outer space is about 60% of that value. This measure is called the atmospheric **transmissivity**. The atmosphere acts as an energy-absorbing layer that drives energy into outer space and back to the Earth, heating it. The atmospheric transmissivity, the terrestrial albedo, the energy balance described in the previous paragraph and expression (1) imply that the temperature of the Earth-atmosphere system seen from outer space is 255 K (-18 °C) and the Earth's surface temperature is about 289 K (16 °C).

Impact of GHG on the energy balance of the Earth-atmosphere system

GHG modulate the energy absorption capacity of the atmosphere because they have electromagnetic energy absorption modes at wavelengths overlapping those of the terrestrial infrared radiation, and their concentration will therefore affect the transmissivity of the atmosphere. The higher the GHG concentration in the atmosphere, the lower its transmissivity. Other factors also affect the transmissivity of the atmosphere or the Earth's albedo – such as the concentration of aerosols, which are small particles or suspended chemical elements in the various layers of the atmosphere, including ash from volcanoes, and dust or residues resulting from human activity – but there is a high degree of certainty that the effect of GHG dominates the others.

In a thermal equilibrium, the temperature at the surface of the Earth must be such that the solar energy hitting the Earth, discounting the effect of the reflection measured by the albedo, is equal to the energy radiated to the outer space by the Earth, discounting the retention effect of the atmosphere measured by transmissivity. Unfortunately, this is not the case. Recent measurements[8] for the period 2000-2005 (Trenberth and Tarullo 2012) point to an average energy imbalance of around $\mathbf{watt \cdot m^{-2}}$ tending to increase the energy absorbed by the Earth. For the equilibrium to be restored it is necessary that, according to equation (1), the Earth's

7. When a surface with water is heated by the Sun or other heat sources, a part evaporates. In the case of plants, the loss of water through sunlight occurs through transpiration. These two phenomena are called evapotranspiration, which tends to heat the atmosphere and cool the surface.
8. These measurements are subject to errors and fluctuations over time and are therefore often reviewed.

surface temperature increases in such a way that the electromagnetic energy radiated by the Earth compensates for the current excess. This is an indication that under current conditions the Earth's surface is expected to heat. This gives rise to the term "global warming".

GHG constitute a small part of the atmosphere, accounting for less than 1% of its contents. It may be surprising for some that the main GHG is water vapour, i.e., the gas phase of water (approximately 5000 ppm). This gas determines a large part of its electromagnetic absorption areas in the infrared range. However, the concentration of water vapour cannot increase indefinitely because it will eventually be returned to the Earth's surface in the form of precipitation.

Other GHG, such as carbon dioxide and methane (CH_4), can accumulate indefinitely and that is why they sustainably disturb the atmosphere. Of these, the most important is CO_2, whose concentration has risen steadily since the mid-nineteenth century, from around 285 ppm in 1850 to 410 ppm in 2019. The rate of increase between 2009 and 2018 was around 2.3 ppm per year. Much of this increase is due to human action, in particular the burning of fossil fuels for energy, which transfers to the atmosphere the carbon accumulated by plants for millions of years.

Since the beginning of the industrial revolution, there has been an imbalance between anthropogenic carbon emissions to the atmosphere and its return to the Earth. At present, annual carbon emissions from combustion of fuels (around 9.5 GtC) and land use change (around 1.5 GtC) are only partly offset by their uptake by the oceans (around 2.5 GtC) and by vegetation and other absorption processes on the land surface (around 3.2 GtC). The difference of 4.9 GtC per year (equivalent to 2.3 ppm as mentioned above) accumulates in the atmosphere, leading to a reduction in transmissivity and exacerbating the energy imbalance referred to above. This is why, in order to have an energy balance similar to that of the pre-industrial period, it would probably be necessary to have a concentration of CO_2 and other GHG in the atmosphere similar to that of that period.[9]

Additional effects of global warming

A likely consequence of the current global warming trend is an increase in the frequency of extreme events such as droughts, floods and heat waves. This type of phenomenon has also economic implications, but its characterisation goes beyond the scope of this text. The reader is directed to the summary for decision-makers of IPCC (2021), in particular section B.2 on the increase of extreme climate events.

It should be noted that the increase in GHG concentration tends to trigger positive or negative feedback phenomena. An example of positive feedback is as follows. As higher temperatures increase the capacity of the atmosphere to retain water vapour, which is a GHG, the initial increase in temperature will lead to a higher concentration of water vapour, which in turn will increase the greenhouse effect and consequently the temperature. There are examples of negative feedback (e.g., via change in the albedo), but the general consensus is that the net effect is to amplify the disturbances induced by an increase in GHG concentration in the atmosphere. While these effects are considered in the most sophisticated climate models, powerful feedback loops may occur and disrupt the global climate system or localised climates. Examples are the faster than expected disappearance of permafrost (the soil layer permanently below the freezing point, typical of latitudes close to the poles), the abrupt melting of glaciers leading to a rapid rise in sea level, among others. It is suggested to read section C.3 of IPCC (2021) on low probability global climate trajectories and high disruptive potential.

9. See Figure SPM.10 of IPCC (2021).

Box 2 • Impact of tax mitigation policies: an example

This box is based on Adão et al. (2021) and, although it is not an economic projection exercise, it allows the effectiveness of different fiscal mitigation policies to be assessed. The model draws on the IAM methodology and considers a two-way feedback system: human economic activity affects the climate and vice versa. The model includes modules for four phenomena: climate, carbon cycle, damage and economy. The economy module consists of consumers and producers. Their actions determine carbon emissions. The damage module sets out how the economy is affected by the climate. The carbon module specifies the relationship between carbon emissions and carbon concentration in the atmosphere. Finally, the climate module links carbon concentration to climate.

Before proceeding with the exercise, it should be noted that many estimates of climate change costs from IAM can be considered low given that climate change is one of the most important global problems of our time. According to Hassler and Krusell (2018), the central estimates for the costs of global warming in a no-policy-change scenario is around 1% of world GDP at present and will be around 3% in 100 years for a standard IAM. These figures may seem low, but they mask huge heterogeneity between countries and regions and are much higher than other classic macroeconomic costs. The costs of business cycle fluctuations (expansions and contractions in activity and employment) or inflation costs are substantially lower. In current models, parameters of economic damage or climate sensitivity can produce higher values, but additional research will be needed to improve estimates. Other limitations to these models – such as the existence of a tipping point that would trigger additional disruptive phenomena, uncertainty about the parameters to be used or the absence of migration to colder areas – will be mitigated as economic research progresses.

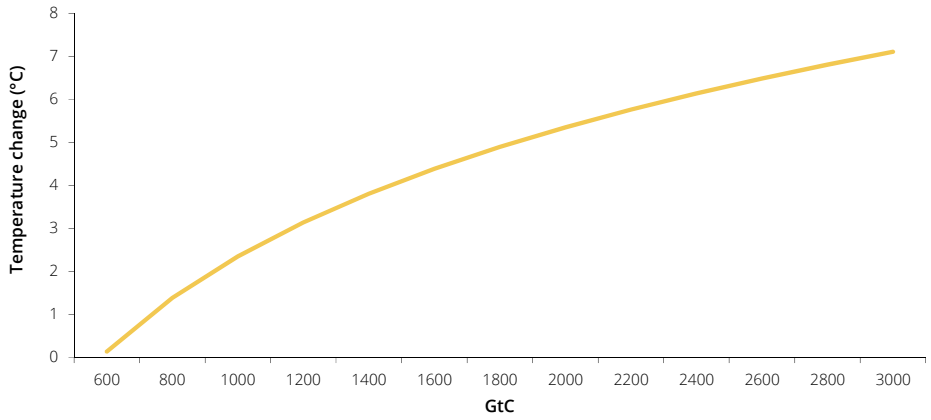
The aim of the climate module is to determine how the concentration of carbon in the atmosphere affects it. The module considers the simplest description of the climate: a function that relates carbon concentration in the atmosphere to the global average temperature. As seen in Box 1, the global average temperature is a growing function of the carbon stock in the atmosphere. Chart C2.1 illustrates this relationship. The horizontal axis ranges from 600 GtC to 3000 GtC, corresponding respectively to pre-industrial levels and higher estimates of available total fossil fuel stocks.[10]

In order to extrapolate the results for the Portuguese case, the statistical relationship between the global average temperature and in Portugal is obtained from historical data presented in the climate data section, using a simple linear statistical model. Estimates indicate that, for an increase in global temperature of 1°C, the average temperature in Portugal increases by 0.59 °C. This is due to Portugal's geographical location and its relatively large Atlantic coast.

The carbon cycle module is a simple relationship between carbon emissions and their concentration in the atmosphere. There is a part of the emissions leaving to the biosphere, a part that remains in the atmosphere for all times and a remaining part that falls at a geometric rate. At the beginning of the century, annual emissions were around 0.5 GtC, reaching around 10 GtC in recent years. Global carbon concentration in the atmosphere has consistently increased: from 630 GtC in 1900 to around 860 GtC in 2017. Chart C2.2 shows the observed data on atmospheric carbon concentration and the expected atmospheric concentrations of the model over time. It is observed that the model is close to the complex dynamics of atmospheric carbon concentration.

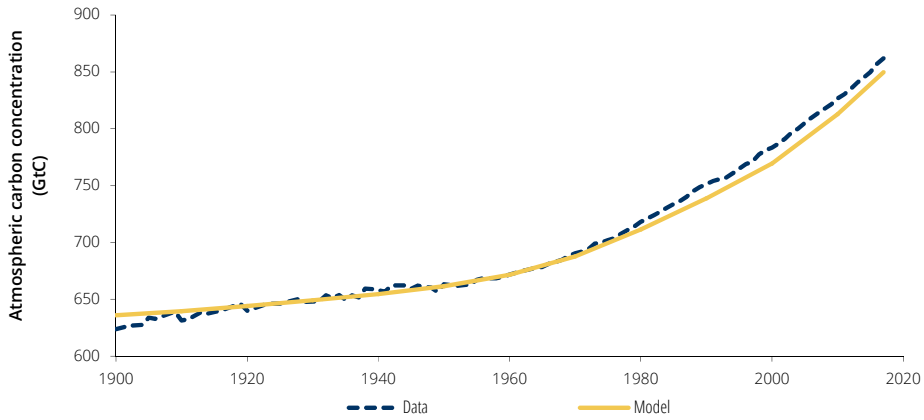
10. For the units used in the literature on GHG concentration in the atmosphere, see Box 1.

Chart C2.1 • Average temperature change as a function of carbon stock in the atmosphere



Source: Adão et al. (2021).

Chart C2.2 • Atmospheric carbon concentration in the period 1900-2017



Sources: https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions and Adão et al. (2021).

The third part of the model specifies how the economy is affected by climate change. There is a high degree of uncertainty about how global climate change can affect the economy, which is reflected in the literature estimates seen in the section on quantifying economic impacts. In addition, many of the losses relate to goods and services without market prices, and examples are the costs of biodiversity loss or involuntary migration and conflicts that may arise from them. Other sources of variability in estimates are the weight given to future generations (Box 3) and technical progress, which could find cheap and workable solutions to this problem. For these reasons, estimates of the impact of climate change should be considered as very imprecise assessments of actual values.

It is assumed in this exercise that economic losses from global warming are proportional to GDP and a function of carbon concentration (Golosov et al. 2014 and Acemoglu et al. 2016), amounting to 0.5% of GDP for every additional 100 GtC of carbon in the atmosphere.

There is only one final consumer good in the economy and all markets are competitive. There is an infinite life representative family that disregards future consumption of the final good. Labour is provided in an inelastic way. The production of the final good requires capital, labour and energy and is negatively affected by carbon concentration. Energy can be produced in the fossil fuel sector or in the renewable sector. To produce energy from fossil fuel it is necessary to use capital and fossil fuel. The use of fossil fuel leads to a direct increase in carbon in the atmosphere. The energy production of a renewable energy firm depends on the capital employed, its productivity and the technology adoption rate. Capital can be raised at no cost for any of the three productive activities using it, and depreciates completely over a period, defined as ten years.

The productivity of a renewable energy firm improves with its own technology adoption rate, but also with the aggregate technology adoption rate in the sector. There is an internal synergy effect in the renewable sector, as any firm also benefits from others adopting new technologies. This creates an externality, leading to a discrepancy between the equilibrium and desirable levels of adoption of new technologies in the renewable energy sector. The synergy effect leads to a general under-investment in renewable energy. There is also a cost of adopting the technology, subtracted from the firm's production.

The optimal policy takes into account the two distortions in the economy. The first is under-investment in the adoption of technology in the renewable sector. The second is the excess energy production in the fossil fuel sector due to environmental externality. Both distortions can be fully accommodated through the use of two independent instruments: (i) a policy that taxes renewable energy firms in proportion to their under-investment and leaves them indifferent between paying the tax or adopting the optimal level of investment; and (ii) a Pigouvian tax on fossil fuel energy that is uniformly passed on to households.

The model is calibrated to assess the interaction between the two policy instruments. More precisely, it is assessed how the two policies would affect the share of renewable energy in the total energy consumed, GHG accumulation, global temperatures and well-being, first on its own and then together. This makes it possible to assess the potential substitutability between the two policy instruments.

Model parameters are chosen to represent the current productive equilibrium in various dimensions at the starting point, including large macroeconomic aggregates, recent growth in the share of renewable energy in total energy produced, carbon dioxide stock in the atmosphere[11] and its rate of growth. A logarithmic utility function and a discount rate of 4% per annum are used (Box 3). The long-term growth rate of the economy is 2% per annum. Population is constant. For this set of parameters, the optimal tax is about USD 25 per tC and the initial tax is 40% lower than this.[12] In the relevant scenarios, this policy is implemented already in the first period.

The model is simulated by considering different scenarios for the two policies. In addition to the scenario without changing the policy parameters, there are three other cases: the imposition of the Pigouvian tax without a policy of optimal adoption of technology in the renewable sector; the implementation of the optimal policy of technological adoption in the renewable sector without

11. The initial value of the temperature anomaly relative to the pre-industrial period of 1.4°C is somewhat higher than the range given in the climate data section. That assumption has no impact on the exercise.

12. Barrage (2014) considers different parameterisations of the model of Golosov et al. (2014) and, for the functional forms and discount factor used in Adão et al. (2021), obtains a similar value for this tax.

the imposition of the Pigouvian tax; and the simultaneous implementation of both policies. Chart C2.3 shows the trajectories for the share of renewable energy in the total energy consumed (Panel A), the cumulative fossil fuel consumption (Panel B) and the global temperature (Panel C), for each policy scenario and in the case where the initial policy parameters are maintained throughout the simulation.

According to Panel A of the chart, optimal technology adoption policy makes the trajectory steeper. The adoption of the technology at its optimal level, in the absence of the optimal Pigouvian tax, tends to decrease the share of renewables in the short term compared to the scenario without policy change; on the other hand, it is anticipated that all energy produced is renewable.[13] This is an instance of the "green paradox": in the absence of the optimal Pigouvian tax, anticipating a cheaper renewables regime decreases the fraction of renewables production in the short term. By contrast, imposing an optimal Pigouvian tax in the absence of a policy that induces the adoption of technology increases the fraction of renewable energy immediately. Finally, both policies at the optimal level reduce the share of renewable energy in the short term, but the transition to a fully renewable global economy will take place by 2070, well ahead of the other scenarios.

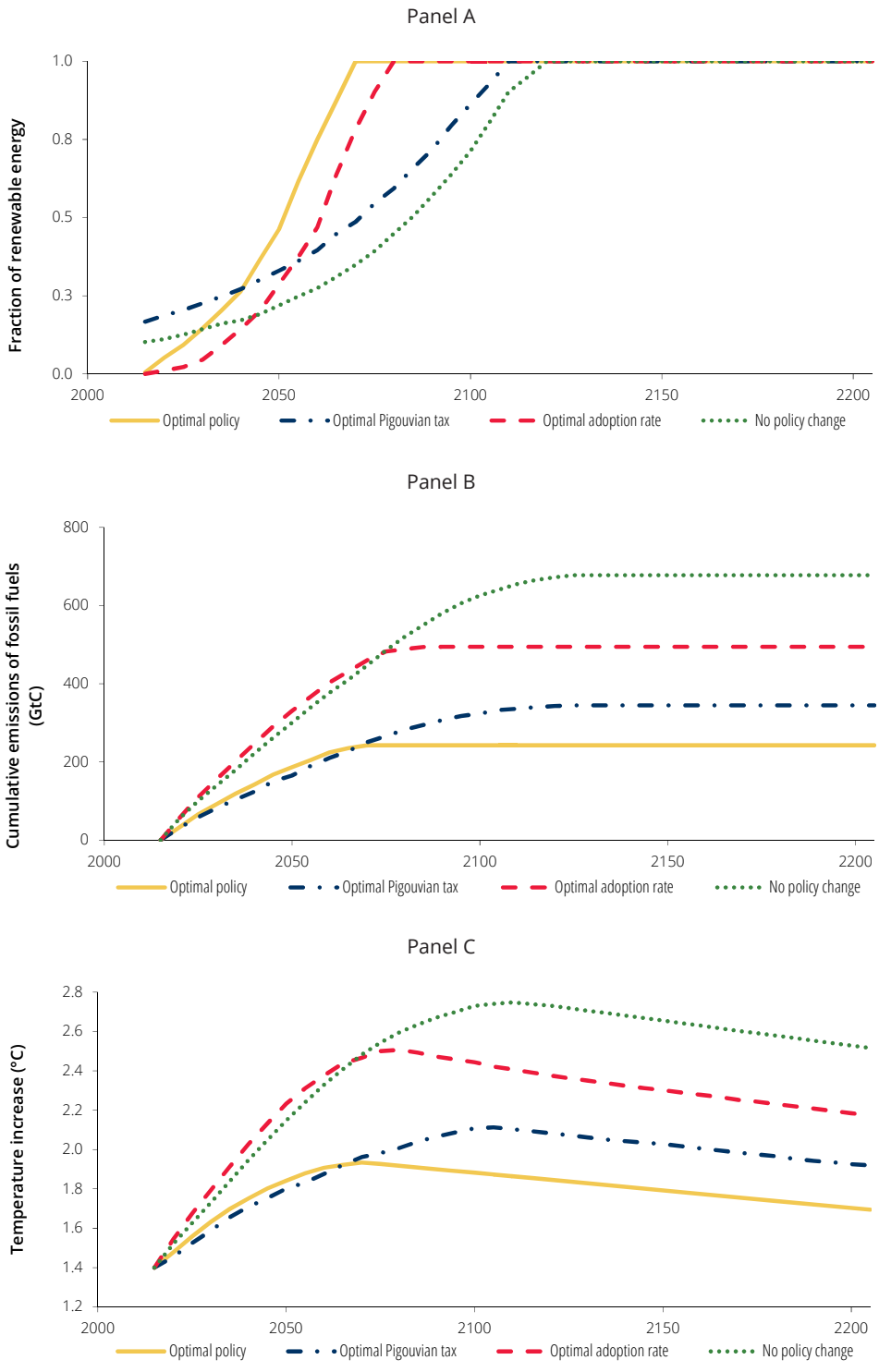
In general, fossil fuel consumption will fall to zero when renewable energy productivity reaches a limit. Under the optimal Pigouvian tax, fossil fuel consumption is endogenously limited. In that case, the balance of the economy is such that fossil fuel consumption falls to zero in finite time, and not just asymptotically. The reason for this is that fossil fuels and renewable energies are considered perfect substitutes for the production of the final good. Thus, as fossil fuel consumption disappears, its marginal productivity in units of the final good, which depends on marginal energy productivity, remains finite. As emission damage grows in proportion to GDP, it comes to a point where renewable energy productivity is high enough to make fossil fuels obsolete.

Panel B describes the evolution of cumulative fossil fuel consumption in the four scenarios. Interestingly, in the absence of a GHG tax and optimal adoption of technologies in the renewable sector, the cumulative consumption of fossil fuels is initially somewhat more intense than in the no-policy-change scenario, consistent with the top panel. Faster growth in renewable energy productivity allows the economy to rely entirely on renewable energy earlier. Similarly, when the Pigou tax and the adoption of the technology are defined at their optima, the economy achieves exclusive use of renewable energy earlier, and more fossil fuel is left unused. Consistent with the "green paradox", there is initially more intensive use of fossil fuel than in the case where the optimal Pigouvian tax is in place and technology adoption policy in the renewable sector is absent.

In line with the use of fossil fuel in the top panel, the global temperature increases significantly in the baseline and optimal adoption of technology, reaching about 2.8 °C above the pre-industrial level (Panel C). Under the optimal Pigouvian tax or with both optimal policies, global temperatures peak at around 2.2 °C and 2.0 °C above the pre-industrial level, respectively, and then decrease over time.

13. The initial sharp variations in the fraction of renewable energy are due to the simplifying assumption that capital is cost-free mobile between its three possible uses: production of the final good, fossil energy and renewable energy. This assumption is only relevant at the outset, given the complete depreciation, and has a limited impact on the results.

Chart C2.3 • Results of simulations in the four scenarios



Source: Adão et al. (2021).

In terms of welfare, the gain from the optimal technology adoption policy is equivalent to a permanent increase in consumption of 0.25% compared to the no-policy-change scenario, while the optimal Pigouvian tax implemented in isolation would result in a gain of 1.02%, confirming the relative importance of the carbon tax. In the case where the two policies are implemented, the welfare gain is 1.43%. The difference between this figure and the sum of the two previous ones (0.16%) leads to another of the conclusions of this analysis: there is considerable complementarity between the two policies. Thus, the model points to additional welfare gains when policies are adopted at the same time.

In Portugal, for the same global carbon dioxide emissions the temperature increase should be lower. Using a linear regression analysis applied to temperature data for the whole surface of the Earth and Portugal, reported in the section on climate data (Charts 1 and 3), it appears that the temperature in Portugal increases by 0.6 °C when the global temperature increases by 1 °C. As the change in global temperature will be between 2 and 2.8 °C, depending on whether or not climate policies are adopted, the temperature change in Portugal will range between 1.2 and 1.7 °C, and its evolution is qualitatively similar to that in Chart C2.3.

Assuming that the damage function is valid for Portugal, we obtain GDP losses that depend on the policy and are between 0.4% and 0.8%. The equivalent gain in consumption for Portugal with the simultaneous adoption of the two optimal policies is around 0.4%. This corresponds to a welfare gain equivalent to an additional €520 million in consumption, at constant prices every year thereafter. It should be stressed, however, that these figures are not projections, but are merely intended to assess the possible effects of different mitigation tax policies. This estimate is also subject to all the reservations mentioned in the section on the quantification of economic impacts and, from a stress test perspective, could easily increase by an order of magnitude, as in the Swiss Re Institute (2021).

Box 3 • The discount factor in the economic analysis of long-term policies

From an economic point of view, the assessment of the welfare of an economic agent is based on considering its current utility and discounting its future utility for the present time. The utility at each moment can be measured in a variety of ways, usually related to consumption or income and to the amount of leisure enjoyed in each period. Their use is implicit, for example, in the estimates in Table 1, as different discount rates will correspond to different decision-making rules of economic agents and thus different levels of GDP over the horizon used. This box proposes figures to be used when assessing the impacts of very long-term policies, not necessarily related to climate change.

The idea that future costs or benefits are less relevant than the same value at present is a fundamental principle in economics. This principle is typically implemented by discounting a future value by multiplying it by a factor lower than the unit. Today's value, V_0, of a flow V_t to be generated in t years is given by

$$V_0 = V_t \left(\frac{1}{1+\rho}\right)^t \quad (2)$$

where ρ is the discount rate.

Climate change occurs over very long horizons, at least tens of years. This means that it is within this long time horizon that any economic assessment of the consequences of climate change as well as the costs and benefits of public policies aimed at minimising its impact should be framed. To the extent that the costs generated by such changes are projected for the future, and the costs and benefits of public policies will tend to occur at different times, it is necessary to establish how economic values will be assessed over time, i.e., how future values will be discounted. A high discount rate reduces the current value of future flows, minimising their relevance. A low value results in opposite consequences.

Public policies with long horizons should adopt a methodology where the interests of future generations are taken into account. The direct implication is that the methodology should be informed by welfare criteria, using a method inspired by Ramsey (1928) and based on discounting marginal rates of substitution between consumption in different periods in an aggregate model with economic growth. The equation proposed in this analysis is given to Gollier (2002):

$$\rho = r + \gamma\mu - \frac{1}{2}\gamma^2\sigma^2 \quad (3)$$

where μ is the growth rate of per capita consumption, γ is the elasticity of the marginal utility of consumption, i.e., the curvature of the utility function of consumption, r is the pure intertemporal discount rate (which should be used to update the utility of consumption rather than consumption directly), σ is the standard deviation of the growth rate of per capita consumption, and ρ is the social discount rate to be applied in the assessment. The interpretation of each term on the right side of equation (3) is simple. The first is a discount rate that reflects the impatience of economic agents, i.e., the idea benefiting from something at a given moment preferable to delaying that enjoyment. The second term incorporates the expectation that per capita consumption will grow in the future, which means giving more weight to the marginal utility of current consumption. It is therefore a question of incorporating a wealth effect at the discount rate, and the value of this term increases with the growth rate of per capita consumption and with the elasticity of marginal utility. The third term adjusts the discount rate to the uncertainty inherent in economic growth and is negative because agents are risk-averse. The greater the uncertainty of consumption growth and the elasticity of marginal utility, the greater the magnitude of this adjustment.

The calibration of these values depends on the type of application and the model itself to be used, if any. The pure discount rate has not an unambiguous calibration. One possibility is to

calibrate it by looking at the real return on after-tax risk-free investments. For Portugal this figure is close to 0.5% per year.[14] This return, however, is greatly affected by current real interest rates; for example, in the 1990s these figures were in the range of 1-3%. Another possibility is to use calibrations of economic literature, where values can be found between 1% and 4% per year. The elasticity of marginal utility depends on the concavity of the utility function in consumption; a logarithmic utility function in consumption is equivalent to unit elasticity. Some countries use higher values, the median value being close to 1.5 (Economides et al. 2018) The annual growth rate of per capita consumption can be measured in the data; reasonable values for developed countries will be in the range of 1-3%. Finally, the uncertainty parameter can also be measured in the data and again for a developed country its value should be in the range of 1-4% per year.

It follows from this discussion that, taking into account the ranges of values mentioned above for the various parameters, the value of the annual discount rate to be applied is between 1.4% and 7% for unit elasticity, and between 1.8% and 8.5% for an elasticity equal to 1.5. These ranges are broad and invite examining the robustness of results to this parameter in the assessment of long-term policies. In illustrative terms, with a discount rate of 4%, the discounted value of a given flow in ten years is reduced by about one third.

14. This figure applies to Portuguese public debt after tax for the period 1996-2018, excluding the period 2009-2014, which was heavily affected by the euro area public debt crisis.

References

Acemoglu, D., Akcigit, U., Hanley, D. and Kerr, W. (2016). "Transition to clean technology". *Journal of Political Economy* 124.1, pp. 52–104.

Adão, B., Narajabad, B. and Temzelides, T. (2021). "Scrapping, Renewable Technology Adoption, and Growth". *Working Paper* No 11, Banco de Portugal.

Adar, Z. and Griffin, J.M. (1976). "Uncertainty and the choice of pollution control instruments". *Journal of Environmental Economics and Management* 3.3, pp. 178–188.

World Bank (2021). State and Trends of Carbon Pricing 2021. Washington, DC.

Barrage, L. (2014). "Sensitivity Analysis for Golosov, Hassler, Krusell, and Tsyvinski (2014): 'Optimal Taxes on Fossil Fuel in General Equilibrium'". Supplemental material for Golosov et al. (2014).

Cattaneo, C. and Peri, G. (2016). "The migration response to increasing temperatures". *Journal of Development Economics* 122, pp. 127–146.

Cavalcanti, T., Hasna, Z. and Santos, C. (2021). "Climate Change Mitigation Policies: Aggregate and Distributional Effects". *Working Paper* No 17. Banco de Portugal.

Cornes, R. C., van der Schrier, G., van den Besselaar, E. J. M. and Jones. P. D. (2018). "An Ensemble Version of the E-OBS Temperature and Precipitation Datasets". *Journal of Geophysical Research: Atmospheres* 123.17, pp. 9391–9409.

Deryugina, T. and Hsiang, S. M. (2014). "Does the environment still matter? Daily temperature and income in the United States". *Working Paper* 20750. National Bureau of Economic Research.

Economides, G., Papandreou, A., Sartzetakis, E. and Xepapadeas, A. (2018). *The Economics of Climate Change.* The Bank of Greece.

Fankhauser, S. and Tol, R. S. J. (2005). "On climate change and economic growth". *Resource and Energy Economics* 27.1, pp. 1–17.

Gassebner, M., Keck, A. and Teh, R. (2010). "Shaken, Not stirred: The Impact of Disasters on International Trade". *Review of International Economics* 18(2) pp. 351–368.

Gollier, C. (2002). "Discounting an uncertain future". *Journal of Public Economics* 85.2, pp.149-166.

Golosov, M., Hassler, J., Krusell, P., and Tsyvinski, A. (2014). "Optimal taxes on fossil fuel in general equilibrium". *Econometrica* 82.1, pp. 41–88.

Hassler, J. and Krusell, P. (2018). "Environmental Macroeconomics: the Case of Climate Change". Chapter in *Handbook of Environmental Economics*.

Hassler, J., Krusell, P., Olovsson, C. and Reiter, M. (2020). "On the effectiveness of climate policies". *Working Paper*. IIES

Haylock, M.R., Hofstra, N., Klein Tank, A. M. G., Klok, E. J., Jones, P. D. and New, M. (2008). "A European high resolution gridded data set of surface temperature and precipitation for 1950-2006". *Journal of Geophysical Research: Atmospheres* 113.D20.

Hsiang, S., Kopp, R., Jina, A., Rising, J., Delgado, M., Mohan, S., Rasmussen, D. J., Muir-Wood, R. Wilson, P., Oppenheimer, M., Larsen, K. and Houser, T. (2017). "Estimating economic damage from climate change in the United States". *Science 356*, pp. 1362–1369.

IPCC (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Main drafting team Pachauri, R. K. and Meyer, L. A. (eds.). IPCC, Geneva, Switzerland, 151 pp.

IPCC (2021). *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Edited by Masson-Delmotte, Zhai, V., P., Pirani, A., Connors, S.L., Péan, C., Berger, S., Caud, N., Chen, Y., Goldfarb, L., Gomis, M.I., Huang, M., Leitzell, K., Lonnoy, E., Matthews, J.B.R., Maycock, T.K., Waterfield, T., Yelekçi, O., Yu, R., e Zhou, B. (eds.). Cambridge University Press.

Matsuura, K. and Willmott, C. J. (2018a). "Terrestrial Air Temperature: 1900-2017 Gridded Monthly Time Series". url: http://climate.geog.udel.edu/~climate/html_pages/Global2017/README.GlobalTsT2017.html (accessed 15/09/2020).

Matsuura, K. and Willmott, C. J. (2018b). "Terrestrial precipitation: 1900-2017 Gridded Monthly Time Series". url: http://climate.geog.udel.edu/~climate/html_pages/Global2017/README.GlobalTsP2017.html (accessed 15/09/2020).

Moody's (2019). The Economic Implications of Climate Change. https://www.moodysanalytics.com/-/media/article/2019/economic-implications-of-climate-change.pdf

Nordhaus, W. (2006). "Geography and Macroeconomics: New Data and New Findings'. *Proceedings of the National Academy of Sciences* 103: 10, 3510-3517.

Noy, I. (2009). "The macroeconomic consequences of disasters". *Journal of Development Economics* 88, pp. 221–231

Oh, C. H. and Reuveny, R. (2010). "Climatic natural disasters, political risk, and international trade". *Global Environmental Change* 20, pp. 243–254.

Parker, M. (2018). "The Impact of Disasters on Inflation". *Economics of Disasters and Climate Change* 2(1), pp. 21–48.

Páscoa, P., Russo, A., Gouveia, C. M., Soares, P. M. M., Cardoso, R. M., Careto, J. A. M. and Ribeiro, A. F. S. (2021). "A high-resolution view of the recent trend over the Iberian Peninsula". *Weather and Climate Extremes* 32.100320, pp. 1–9.

Ramsey, F. P. (1928). "A Mathematical theory of saving". *Economic Journal 38*,152, pp. 543–559.

Rigaud, K., de Sherbinin, A., Jones, B., Bergmann, J., Clement, V., Ober, K., Schewe, J., Adamo, S., McCusker, B., Heuser, S. and Midgley, A. (2018). "Groundswell: Preparing for Internal Climate Migration". World Bank, Washington DC.

Rose, B. (2021). The Climate Laboratory. University of Albany. https://brian-rose.github.io/ClimateLaboratoryBook/home.html.

Stavins, R. N. (1996). "Correlated uncertainty and policy instrument choice". *Journal of Environmental Economics and Management* 30.2, pp. 218–232.

Swiss Re Institute (2021). The economics of climate change: no action not an option. April. https://www.swissre.com/dam/jcr:e73ee7c3-7f83-4c17-a2b8-8ef23a8d3312/swiss-re-institute-expertise-publication economics-of-climate-change.pdf

Tol, R. S. J. (2018). "The Economic Impacts of Climate Change". *Review of Environmental Economics and Policy* 12(1), pp. 4–25.

Trenberth, K. E. and Fasullo, J.T. (2012). "Tracking Earth's energy: From El Niño to global warming". *Surveys in Geophysics* 33.3-4, pp. 413–426.

Weitzman, M. L. (1974). "Prices vs. quantities". *Review of Economic Studies* 41.4, pp. 477–491.