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Quarterly Report on the Euro Area

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EUROPEAN ECONOMY

The value of unity

Economic and
Financial Affairs

The **Quarterly Report on the Euro Area** is written by the staff of the European Commission and coordinated by the Directorate-General for Economic and Financial Affairs under the direction of Maarten Verwey. It is intended to contribute to a better understanding of economic developments in the euro area and to improve the quality of the public debate surrounding the area's economic policy.

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Maarten Verwey
Director-General

The strong rebound of economic activity in the first quarter of this year, pulled the euro area out of the recession registered in the last two quarters of last year. Though short-lived and mild the recession followed a prolonged period of weak performance. The high cost of living has held back real disposable income growth while high debt repayment costs have continued to push up the saving rate of households – delaying the expected rebound of consumption. Investment also disappointed, held back by tight financial conditions and elevated uncertainty. Global merchandise trade was also particularly weak throughout last year, though a stronger contraction of imports than exports, resulted in a positive contribution of net external demand, tough the latter was largely offset by the drag of an unusually large inventory cycle. At the same time, weak economic activity supported the disinflationary process which progressed at somewhat faster pace than anticipated. Inflation came down from a peak of 10.6% in October 2022 to 2.4% in April 2024. The labour market, in turn, has proved extremely resilient, with headcount employment continuing to expand throughout Q4-2023. As headwinds from tight monetary policy abate, global trade rebounds and real wages expand further, the conditions are in place for a continued economic expansion of economic activity in 2024 and a further acceleration in 2025.

In our central scenario, inflation is set to continue its descent towards the 2% medium-term ECB target. Certain factors may however slow down the disinflation process. Though labour market tightness and nominal wage growth moderate, growth in real wage is set to continue. Wage increases are expected to be absorbed by productivity gains and a further reduction in profit margins, but this is not to be taken for granted. Furthermore, in certain large HICP categories, particularly services, inflation is showing considerable stickiness.

Given the continued prominence of inflation in the economic policy debate, this issue of the Quarterly Report on the Euro Area features three analytical chapters revolving around inflation. The first chapter analyses the impact of higher inflation generated by an adverse terms-of-trade shock on public debt sustainability. The second chapter discussed the channels through which climate change - and endeavours to mitigate or adapt to it - may affect inflation. Finally, the third chapter analyses how a sectoral wage shock interacts with the structure of the economy and propagates into inflation.

The first chapter looks at the impact on public debt of an adverse terms-of-trade shock. Even though inflation erodes the real value of nominal debt, simulations with the European Commission's QUEST model suggest that, if the source of inflation is an adverse terms-of-trade shock, the government public debt-to-GDP ratio is likely to increase. Under a terms-of-trade shock, the debt-reducing effect of higher inflation is outweighed by the adverse effects of slower real growth, a lower primary budget balance, and higher interest rates as monetary policy fights inflationary pressures. The source of the inflationary shock is crucial as in the model at demand-driven inflation would have opposite implications on debt to terms-of-trade driven inflation. When relating these stylised results to the recently observed inflation and debt developments, it should be noted that the inflation increase was driven by a combination of different economic shocks, including both a set of terms of trade/supply shocks and demand shocks.

The second chapter of this issue looks beyond the short-term and explores the medium-term drivers of inflation, with a focus on climate change. Climate change has become ever more disruptive and threatening to life in many regions of the world. As greenhouse gas emissions continue to grow, amid slow and insufficient mitigation efforts, its impact is poised to become even stronger in the years ahead. In this context, the chapter discusses what climate change and efforts to adapt to it will imply for prices. It highlights how relative price adjustments will play a key role in this process, either due to climate-induced shocks to factor endowments or preferences, or as part of the policy instruments used. Climate change and mitigation are expected to impact a wide array of prices, with those of food and energy particularly affected. While there is substantial uncertainty regarding the orders of magnitude, inflation is expected to become more volatile and subject to upward pressures.

Finally, Chapter 3 analyses how shocks to nominal wages affect consumer prices when considering the sectoral structure of the economy, using an input-output model. The chapter shows that, on top of their direct impact on production prices, wage increases may also have sizeable second round indirect impact on prices via their effect on the cost of intermediate inputs. Moreover, a wage shock in a specific sector can have a vastly different impact on inflation depending on its position in the production chain, with sectors that provide more inputs to the rest of the economy having a larger impact, other things being equal. Measures of stress in the labour market, like the vacancy rate, seem currently relatively concentrated in sectors relatively upstream in the production chain. This means that, if wages grow faster in sectors with higher vacancy rates, this may result in stronger inflationary dynamics than if wages increased by the same rate in all sectors. As also noted above, at present a gradual recovery of real wages appears consistent with a continuation of gradual disinflation in the euro area.

To conclude, let me highlight that in this first issue of the QREA in 2024, we have included a special euro area chronicle, to mark the 25th anniversary of the euro. This special chronicle outlines the history of the euro, from its origins, describing a Monetary Union that has been beneficial to its members, has expanded and has been able to respond and adapt flexibly to the challenges that have come its way. This story deserves to be analysed in more details. For this reason, the next two issues of the QREA will be dedicated to an assessment of the first 25 years of the euro area economy, with a focus on the last 5 years and the exceptional shocks the euro area had to cope with.

I. TERMS-OF-TRADE-DRIVEN INFLATION AND MONETARY-FISCAL POLICIES

By Gergo Motyovszki

Abstract: *This chapter looks at whether the recent sharp spike in inflation can be beneficial for public debt sustainability by eroding the real value of nominal debt. Simulations with the European Commission's QUEST model suggest that, if the source of inflation is an adverse terms-of-trade shock, then it leads to a rising public debt-to-GDP ratio instead. In this case, the debt-reducing effect of higher inflation is outweighed by the adverse effects of slower real growth, a declining primary budget balance, and higher interest rates as an active monetary policy tightens to fight inflationary pressures. The results are policy-dependent: shorter debt maturity (e.g. as brought about by past QE programs) would speed up the rise in interest expenditures, while a more accommodative monetary policy would delay them, also supporting nominal growth. The initial terms-of-trade loss triggers second round domestic price pressures as economic agents strive to recover their purchasing power, and the emergence of such wage-price spirals is found to interact strongly with the reaction of monetary policy. The reaction of the primary fiscal balance (via automatic stabilisers, inflation indexation and debt-stabilisation rules) also matters. However, the baseline result that the debt-to-GDP ratio rises in response to an adverse terms-of-trade shock is fairly robust across all but the most extreme alternative policy scenarios. The source of the inflationary shock is crucial for these results as demand-driven inflation would have opposite fiscal implications. The results of the chapter should not be blindly applied to the observed inflation development, which was driven by a combination of different economic shocks.* (1)

I.1. INTRODUCTION

In 2021-22 Europe experienced a surge in inflation. While high inflation is usually regarded as economically costly, this has also raised the question whether the situation can be beneficial for public finances and debt sustainability. The real value of nominal (i.e. not inflation-indexed) local currency debt can be eroded by faster-than-expected price growth, which could *ceteris paribus* lower public debt-to-GDP ratios. Higher inflation could also raise the budget balance, as tax revenue tends to grow in line with inflation while public expenditure might adjust only with a delay.

However, beyond inflation, debt dynamics depend on a host of other factors as well (e.g. real growth or interest rates), which are likely to change and interact with each other as the shocks at the origin of higher inflation propagate through the economy. Moreover, the precise way these interactions unfold depends on the source of inflation and on how economic policy responds. Therefore, *a priori,* how inflationary shocks might affect debt sustainability is ambiguous.

To investigate these general equilibrium fiscal dynamics after an increase in inflation in a model-consistent way, this chapter presents simulations for the European Union done with the Commission's macroeconomic model, QUEST.

First, as there is no such thing as an "immaculate" inflation shock that leaves the rest of the economy unchanged, it is important to identify the underlying economic shock that caused inflation to rise.

(1) The details of these simulations and the underlying model are published in Motyovszki, Gergő (2023). The Fiscal Effects of Terms-of-Trade-Driven Inflation. *European Economy Discussion Papers*, DP-190 (July 2023), **Error! Hyperlink reference not valid.**.

Inflation can increase due to a positive domestic demand shock, which stimulates growth and puts upward pressure on prices (demand-pull inflation), but it can also result from a negative supply shock, like a rise in domestic markups, commodity prices or a hit to productivity, which depress real growth while leading to higher prices (cost-push inflation). Beyond different outcomes for GDP, monetary and fiscal policies are also likely to react in very dissimilar ways, affecting not just interest payments and the primary balance, but also feeding back to inflation and real growth. Different inflationary shocks therefore have very different implications for debt dynamics, which are a result of a complex interaction of all the above.

Due to surging imported energy prices, over the course of 2021-22 Europe saw its terms-of-trade (ToT) deteriorate by almost 9% cumulatively. While arguably not the only source of rising prices, this was undoubtedly an important driver behind the increase in European inflation. For this reason, the stylised model simulations presented in this chapter isolate the effects of an adverse terms-of-trade shock for the EU as a whole and illustrate the transmission channels of such a disturbance for fiscal dynamics.

It should be noted that the actual evolution of inflation in Europe was driven by a combination of various economic shocks, not only the terms-of-trade shock. Most notably, the post-pandemic reopening with the associated pent-up demand of households, supply-chain disruptions and tightening supply bottlenecks have constituted a complex mixture of demand and supply shocks. However, rather than conducting a historical shock decomposition exercise trying to replicate Europe's recent experience, the analysis in this paper attempts to isolate the effect of the terms-of-trade shock only, in order to capture its transmission channels without confounding the picture with other disturbances.

An adverse terms-of-trade (ToT) shock raises import prices relative to export prices, and thereby drives a wedge between the consumer price index and the GDP deflator. This wedge represents a terms-of-trade loss, that erodes the purchasing power of the domestic economy as a whole, pushing *real gross domestic income* (CPI-deflated nominal GDP) below real GDP. At the same time, the shock depresses real GDP itself, as imported intermediate inputs for domestic production become more costly (supply effect), and the weakening purchasing power of households lowers demand not just for imports but also for domestically produced goods (demand effect). In our baseline scenario monetary policy responds promptly to rising consumer inflation by raising short term nominal interest rates.

The main finding from this exercise is that despite its inflationary effect, an adverse terms-of-trade shock leads to a *rising* public debt-to-GDP ratio. The reason is that the debt-reducing effect of higher inflation is outweighed by the detrimental effects of slower real growth, higher interest rates, and a declining primary budget balance. Despite not considering any *discretionary* fiscal response to the rising cost-of-living, the primary balance falls as a share of GDP, driven mainly by CPI-indexed transfer expenditures (e.g. pensions) at a time when CPI-deflated nominal GDP is falling.

Another finding is that the quantitative results depend crucially on various monetary, fiscal and debt management policy settings. When monetary policy raises interest rates less aggressively in response to inflationary pressures, it slows debt dynamics not only directly via financing costs on government bonds, but also indirectly by supporting aggregate demand, and therefore real growth and inflation. In contrast, a shorter average maturity of the outstanding debt stock increases the speed with which rising short term policy rates pass through into effective government financing costs – a highly relevant scenario when the duration of the *consolidated* government's liabilities has been drastically shortened by past QE programs. The reaction of the primary fiscal balance (via automatic stabilisers, inflation indexation and debt-stabilisation rules) also matters. However, the baseline result that the debt-to-GDP ratio rises in response to an adverse terms-of-trade shock is fairly robust across all but the most extreme alternative policy scenarios (2).

Finally, the simulations highlight the importance of the source of the inflationary shock: a demand-driven inflation of similar magnitude would have qualitatively opposite fiscal implications, *improving* debt sustainability. To the extent that inflation in Europe was driven by both terms-of-trade and demand shocks, the *actual* evolution of public finances reflected a mixture of these two clean effects. Irrespective of which shocks actually dominated in the EU, the takeaway of our analysis is that not all types of inflationary shocks are necessarily beneficial for debt-sustainability. In particular, despite raising inflation, a deteriorating terms-of-trade offers little scope for "inflating away" public debt.

The rest of this chapter is structured as follows. Section I.1. describes the macroeconomic transmission channels of a ToT shock both in the real economy and for inflation, while Section I.2. looks at the fiscal implications of these macroeconomic consequences. Section I.3. considers alternative monetary-fiscal policy settings, while Section I.4. explores other types of inflationary shocks. Section I.5. concludes.

I.2. MACROECONOMIC TRANSMISSION CHANNELS OF A TERMS-OF-TRADE SHOCK

I.2.1. Real income and terms-of-trade loss

The illustrative ToT shock is modelled as an exogenous rise in import prices and is designed such that CPI inflation in the EU rises by 1 percentage point under the baseline scenario (3). Rising import prices have a *direct* first round effect on consumer price inflation as imported goods are part of the final consumption basket – as well as an *indirect* first round effect via imported intermediate inputs in domestic production. To the extent that domestic producers can pass on their rising imported input costs, the price of domestically produced goods in the consumption basket also increases, even before taking into account any second-round effects in the price index of domestic value added, i.e. the GDP-deflator (see top right panel of Graph I.1).

By making Europe's imports more expensive relative to the products it exports, a deteriorating terms-of-trade drives a wedge between final consumer prices (the price of what households consume, including imports) and the GDP-deflator (the price of what the domestic economy produces, including exports) (4). This wedge represents a *terms-of-trade loss*, that erodes the purchasing power of the European economy as a whole. Essentially, the value added Europe produces, expressed in terms of the basket of goods it consumes (i.e. *real gross domestic income*), declines even if the volume of production (real GDP) remained unchanged (see upper left panel of Graph I.1). The ToT loss also has a major impact on the evolution of the trade balance (see bottom left panel Graph I.1), where adverse relative price effects

(2) This might seem to contrast with the observed *fall* of debt-to-GDP across the EU during this period. However, in the very short term after an inflationary shock, actual policy is in fact quite likely to be characterised by these most extreme *stylised* policy scenarios, under which debt-to-GDP declines. These feature a nominal freeze on government expenditures ("benefit erosion"), or non-immediate monetary tightening, even if policy is later adjusted.

(3) The scenario is illustrative and does not intend to capture the actual size of the ToT shock that hit Europe. That said, this calibration implies a cumulative 10% decline of the model economy's ToT during the first two years, which is the same order of magnitude as the EU's observed ToT-deterioration of cumulative 9% over 2021-22.

(4) A corollary to this is that despite sharply increasing CPI inflation, nominal GDP is not necessarily growing as fast. Therefore, for fiscal indicators expressed as a share of nominal GDP, it is the more benign GDP deflator that is the relevant inflation indicator.

initially dominate beneficial volume effects, leading to a deficit and raising the external financing needs of the domestic economy.

In addition to lowering real incomes through the ToT loss, the shock also leads to a fall in real GDP itself. Domestic production is hit both via demand and supply channels. On the demand side, there are two counteracting forces. On the one hand, the declining real income of households depresses their overall consumption, since some of them are liquidity constrained and cannot smooth their consumption in the face of fluctuating real incomes. If consumed in unchanged proportions, this would lower demand not just for imports but also for domestically produced goods, *hurting* GDP. On the other hand, the increase in the relative price of imports induces some substitution away from them and towards domestic goods, which *supports* GDP. In other words, the deteriorating terms-of-trade erodes the purchasing power of the domestic economy, while at the same time also making it more competitive: the negative *income effects* are being counteracted by beneficial *expenditure switching* effects. As Auclert et al (2023) show, the balance of these forces depends on the degree to which consumption smoothing is available (e.g. the share of liquidity constrained households) and on the elasticity of substitution between imported and domestically produced goods ([5]).

In our baseline simulations domestic demand is also hurt via intertemporal substitution channels, as an active monetary policy responds to rising consumer inflation by raising short term nominal interest rates more than one-for-one. The resulting increase in real interest rates discourages spending and consumption smoothing even by non-constrained households.

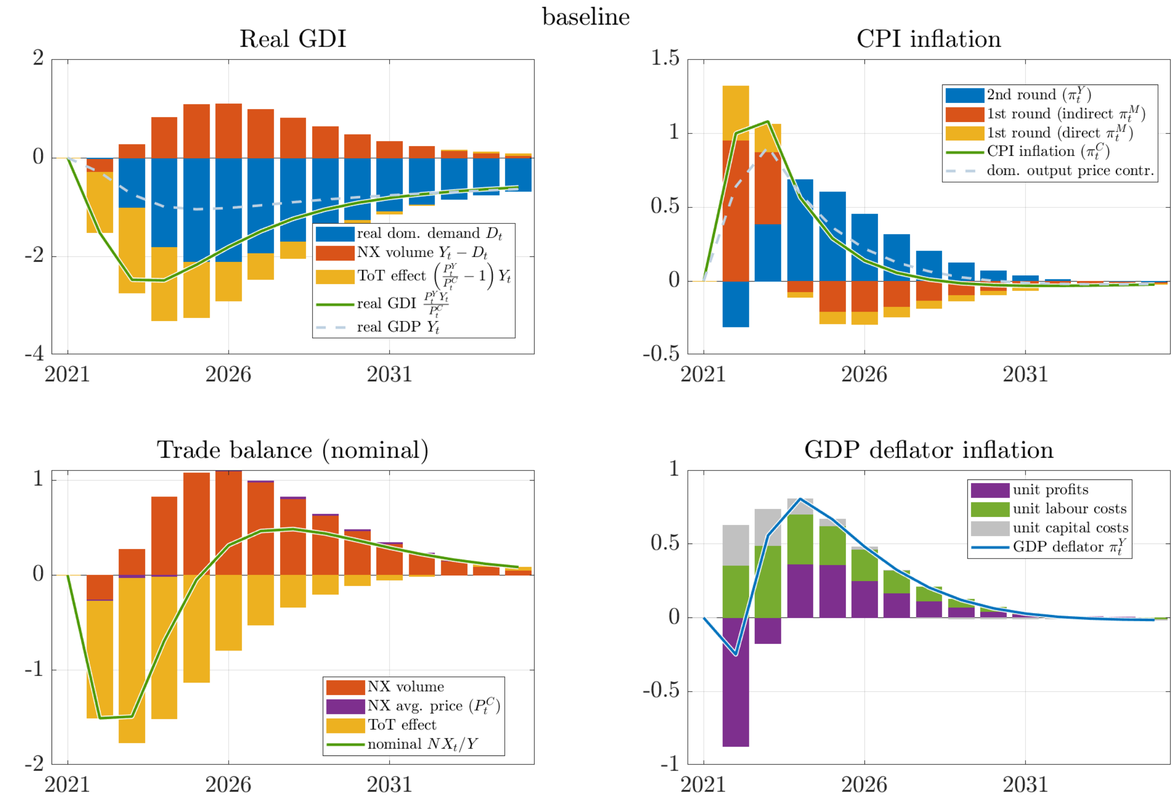
On the supply side, more expensive and imperfectly substitutable imported intermediate inputs raise marginal costs, acting as a cost-push shock, and encouraging domestic firms to scale back production. As Chan et al (2023) show, the strength of this channel depends on the degree of nominal rigidities and the elasticity of substitution between imported inputs and domestic factors of production ([6]). There is expenditure switching also on the supply side, which can constrain the rise in overall marginal costs by prompting firms to shift away from more expensive imported inputs towards relatively cheaper domestic ones, labour and capital. Therefore, even if gross *output* declines, real domestic *value added*, i.e. real GDP does not need to. But with relatively high complementarities in production, such substitution is not strong enough to avoid adverse supply side effects on GDP.

As a result of these demand and supply side forces, real GDP declines in our baseline simulations (see upper left panel of Graph I.1): expenditure switching effects (pulling net exports up) are not strong enough to offset the negative income effects stemming from the terms-of-trade loss, the demand-cooling effects of monetary tightening, and the detrimental effects of more costly complementary inputs on production.

([5]) Auclert, A., Monnery, H., Rognlie, M., & Straub, L. (2023). Managing an Energy Shock with Heterogeneous Agents: Fiscal and Monetary Policy. Mimeo - Harvard University.

([6]) Chan, J., Diz, S., & Kanngiesser, D. (2023). Energy Prices and Household Heterogeneity: Monetary Policy in a Gas-TANK. Bank of England Staff Working Paper, 2023(1041).

Graph I.1: **Macroeconomic effects of an adverse terms-of-trade shock**



Impulse responses to a series of unexpected adverse terms-of-trade shocks, simulated by a two-region version of the QUEST model, for the EU-27. The stylised shocks are calibrated such that CPI inflation rises by 1 percentage point in the first year. Real GDI and GDP are expressed as percentage deviations from their steady state, inflation indicators as percentage point deviation from steady state, while the nominal trade balance is in level deviations expressed as a percentage of steady state GDP. Bars depict contributions to those changes.

Source: European Commission staff calculations.

I.2.2. Second-round domestic price pressures

Following an adverse terms-of-trade shock, on top of the first-round effects of imported inflation, the economy also faces domestically generated price pressures, amid so called second round effects. These are captured by the price index for domestic value added, i.e. the GDP-deflator (see right panels of Graph I.1). To analyse fiscal indicators expressed as a share of nominal GDP, this is the relevant inflation measure, so it is important to understand its dynamics.

The price of domestic value added is an implicit residual, after subtracting the effect of imported input costs from final domestic output prices, with price setting for the latter subject to nominal rigidities. As such, the GDP-deflator is influenced by three counteracting forces (7):

- mechanical effect, due to the changing share of import costs in nominal output (-)
- aggregate demand effects, via domestic slack (-)

(7) Note that often it is only the last force that is meant by "second round effects", but here we use that term more broadly, referring to domestic price pressures on top of (first round) imported inflation, as captured by the GDP deflator.

- attempt to recover real income loss ("wage-price spiral") (+)

To the extent that rising imported input prices do not perfectly pass through to sticky final output prices, the difference must be mechanically absorbed by a lower price of domestic value added. Depending on nominal rigidities, this manifests itself mainly in lower markups for domestic firms, pulling unit profits downwards (see bottom right panel of Graph I.1). However, rising import costs can also be absorbed by cheaper domestic production factors such as labour and capital (especially if complementarities with imported inputs are strong enough), lowering other components of the firm's marginal costs ([8]). Lower wages and capital rental rates would depress unit labour and capital costs, also pulling the GDP deflator downwards via this mechanical effect ([9]).

As we have seen, the adverse ToT shock lowers real GDP and weakens aggregate demand. Larger slack in the economy moderates domestically generated price pressures, as lower production levels imply lower real marginal costs for firms, mainly via softening wage requests from the labour supply side. This is the standard textbook mechanism in the New Keynesian Phillips Curve.

As discussed above, the terms-of-trade loss erodes the purchasing power of the domestic economy *as whole*, making it inevitably poorer as the real consumption value of what it collectively produces declines. Individual domestic agents might try to recover their real income losses, but they cannot *all* escape getting poorer, and at an aggregate level all they can do is shift purchasing power losses among themselves, without managing to raise aggregate real domestic income. In the process, however, this struggle between firms and workers might also fuel domestically generated price pressures, amid what is often referred to as "wage-price spirals", but what is perhaps best described as "wage-price persistence".

Firms would aim to rebuild their reduced markups (prompting them to raise prices), while workers would like to recover losses in the consumption value of their salaries (prompting them to ask for higher nominal wages). Higher wages then raise marginal costs for the firm further, bringing markups back down and fuelling more price increases – which in turn erode the real wage again, fuelling more wage inflation, and so on. This collective (and ultimately failed) attempt to offset aggregate purchasing power losses therefore leads to wage-price dynamics, where inflationary pressures increasingly come from domestic sources and stay persistent ([10]).

The final dynamics of the GDP deflator in our model simulations are the result of the balance of the three channels described above. As the right panels of Graph I.1 show, the mechanical downward effect of incomplete price pass-through and the price moderating effect of weak aggregate demand dominate

([8]) As the Discussion Paper version of this article shows in further sensitivity analyses, this specific pattern of income distribution after an adverse ToT shock (driving the bottom right panel of Graph I.1) is less robust to alternative specifications. E.g. sufficiently stronger complementarities of labour with imported inputs can lead to *rising* unit profits at the expense of unit labour costs. Non-linearities in nominal rigidities (e.g. more flexible prices in a high-inflation environment) might also lead to stronger pass-through supporting profits, and the recent "sellers' inflation" discussion also points towards markups being raised more easily in a high-inflation environment.

([9]) The decomposition of the GDP-deflator used here (and in the bottom right panel of Graph I.1) is somewhat different from other decompositions based on national accounts data. While the latter uses gross operating surplus for firms (profits in the accounting sense), our current approach splits this further into "pure" profits (resulting from market power and markups) and capital costs (that capture the maintenance and opportunity costs of holding physical capital stock).

([10]) Lorenzoni and Werning (2023) interpret the New Keynesian wage-price persistence mechanism fundamentally as a disagreement about the real wage between firms and workers, thereby pointing to a *distributional conflict* as the proximate cause of inflation. As Blanchard (1986) has shown, these inconsistent real wage targets can exist even under fully forward-looking rational expectations, as long as not all price and wage decisions are taken simultaneously – a feature of every New Keynesian model with staggered price (and/or wage) setting. Instead of reaching the new equilibrium real wage instantaneously, the process can be drawn out due to out-of-sync nominal rigidities (with its exact pattern depending on relative price and wage stickiness). See Lorenzoni, G., & Werning, I. (2023). Wage Price Spirals. *Brookings Papers on Economic Activity,* 54(2), and Blanchard, O. J. (1986). The Wage Price Spiral. The *Quarterly Journal of Economics*, 101(3), 543-566.

initially, and the GDP deflator actually *falls* in the first year of the shock ([11]). Later on however, the attempt by domestic agents to recover their real income losses becomes the main driver of domestic price pressures, fuelling positive second-round effects, even as first-round imported inflation subsides. Taken together with the decline in real GDP, the just discussed evolution of the GDP deflator implies that nominal GDP is lower in the first two years of the simulation and becomes higher only thereafter.

I.3. FISCAL EFFECTS OF ADVERSE TERMS-OF-TRADE SHOCKS

In our baseline simulations the primary budget balance declines as a share of GDP in response to an adverse ToT shock (Graph I.2, left panel). Importantly, the baseline scenario assumes no *discretionary* reaction from the side of fiscal policy in response to the cost-of-living crisis and the developing recession, nor in response to the increasing debt-to-GDP ratio ([12]), in order to isolate the effect of the shock from these fiscal decisions.

The widening primary deficit is driven mainly by expenditures such as transfers (e.g. pensions) that are assumed to be indexed to rising consumer prices under our baseline calibration, and which therefore increase as a share of GDP when real GDP declines and the GDP deflator grows less than CPI. Automatic stabilisers such as unemployment benefits also increase as the real economy weakens. Government consumption and public investment are assumed to be fixed as a share of GDP, so they have no effect on the primary balance by construction. These effects depend crucially on the indexation rules of expenditure items ([13]).

Tax revenues increase somewhat (as a share of GDP), mainly due to the "fiscal drag" effect coming from initially not adjusting the nominal brackets of a progressive labour tax system. As the nominal wage distribution shifts into higher tax brackets that are not automatically adjusted in line with wage inflation, the average labour tax rate also increases, raising labour tax revenues as a share of GDP beyond what is implied by a higher labour income share. In addition, VAT revenues also rise because of the opening wedge between the CPI and GDP deflator, while consumption volumes are slower to moderate, so the government can collect taxes on relatively more expensive consumption goods. However, these positive revenue effects are not large enough to offset the effect of higher expenditures, so overall the primary deficit widens.

Overall, the terms-of-trade deterioration leads to an increase in the public debt-to-GDP ratio**.** The right panel of Graph I.2 decomposes the dynamics of the cumulative change in debt-to-GDP, according to the following equation ([14]):

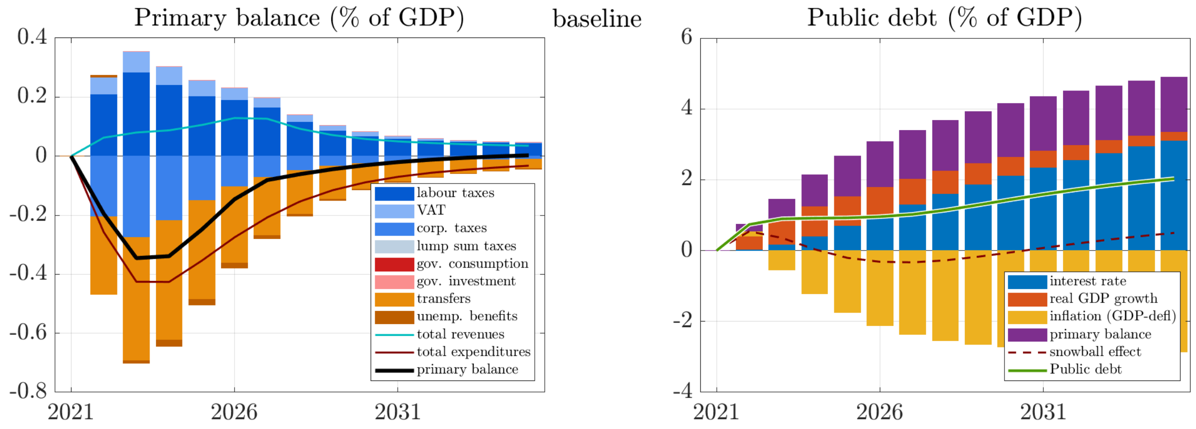
([11]) This baseline result of initially lower GDP deflator as a result of an adverse ToT shock is less robust to alternative monetary policy specifications. In Section I.4. we consider a delayed response from the central bank, under which the aggregate demand channel contributes more positively, resulting in rising GDP deflator already on impact.

([12]) In other words, the debt-stabilising motive in the fiscal rule, that would automatically raise primary balances in response to a rising public debt ratio, is switched off for the first 20 years of the simulation. Beyond this point, a debt stabilising *passive* fiscal rule is restored, in order to prevent conflict with an *active* inflation targeting monetary policy rule, thereby ensuring non-explosive stable model dynamics, amid a coordinated monetary-fiscal policy regime.

([13]) A sensitivity analysis in Section I.4., explores this further and shows alternative indexation rules.

([14]) The cumulative change in the public debt-to-GDP ratio is denoted by $\hat{d}_T$, while pb_t is the primary budget balance as a percent of GDP, i^g_{t-1} is the *effective* nominal interest rate on the outstanding government debt stock, π_t is inflation (GDP-deflator) and g_t is the growth rate of real GDP. The last three terms sum up to the "snowball effect", i.e. the interest-growth differential, which operates *on top of* the effects of inflation and real growth on the primary balance itself. This relationship holds as a matter of accounting identity, and its components may interact with each other, so the individual terms do not perfectly isolate the "effect" of each variable. However, it can still help us to map the transmission channels of the shock propagation.

Graph I.2: **The fiscal effects of adverse terms-of-trade shocks**



Impulse responses to a series of unexpected terms-of-trade shocks, simulated by a version of the QUEST model, calibrated for the EU-27.

Source: European Commission staff calculations.

$$\hat{d}_T = \sum_{t=2022}^{T} \Delta d_t = \sum_{t=2022}^{T} \left\{ -pb_t + \frac{i_{t-1}^{g}}{(1+\pi_t)(1+g_t)} d_{t-1} - \frac{g_t}{(1+\pi_t)(1+g_t)} d_{t-1} - \frac{\pi_t}{1+\pi_t} d_{t-1} \right\}$$

As the chart shows, the debt-reducing effect of (eventually) higher inflation is outweighed by the adverse effects of slower real growth, higher interest rates and a declining primary balance. Monetary tightening in response to higher CPI inflation via raising short term interest rates ([15]) passes through to higher effective interest payments on public debt, albeit only gradually, as government bonds in the EU have a rather long average maturity of 7 years. Rising real interest rates depress real economic growth further beyond the direct recessionary impact of the shock, while also mitigating the rise in inflation itself, all of which contribute to increase debt-to-GDP.

The so called "snowball effect" due to the interest-growth differential is the sum of the blue, red and yellow bars on the right panel of Graph I.2. As one can see, it never becomes too negative (initially even being positive) which is not what the debt-reducing effect of the inflation term alone would imply: higher nominal interest rates and lower real growth counterbalance that. In addition, recall that the relevant inflation measure here is GDP-deflator growth which, despite sharply increasing CPI inflation, builds up only gradually as second round effects on domestic prices gain strength later on.

That said, the snowball term is never too positive, either, which one might expect based on higher short term real interest rates and declining real growth. The reason for this is mainly long-term public debt, which can protect its issuer against rising short term interest rates, and at the same time impose losses from inflation revaluation on bondholders. Although monetary policy makes sure to raise *short term* real interest rate throughout the simulation horizon, the *effective* real interest rate for long term government debt can initially decline, as due to longer maturities the pass-through from higher short term nominal rates is only gradual, while the effect of higher inflation is felt more quickly. Therefore, in our baseline scenario "inflating away" the public debt, in the sense of negative effective real interest rates on

([15]) Monetary policy in QUEST responds to current deviations of CPI inflation from target and to a measure of the output gap (with additional interest-smoothing also applied). This policy rule is more lenient on supply-driven inflation deviations, to the extent that those result in a negative output gap, but the net effect is still an interest rate increase.

government bonds, does happen, even if only to a limited extent and for a contained period of time. It is just more than offset by slower real growth and a declining primary budget balance, such that the debt-to-GDP ratio is higher throughout the simulation.

I.4. ALTERNATIVE MONETARY-FISCAL POLICIES

Various features of economic policy can have major implications for how an adverse terms-of-trade shock affects debt dynamics, which are explored in this section.

I.4.1. Monetary policy and debt management

Monetary policy normalisation in the euro area triggered a discussion where some suggested the ECB and other EU central banks reacted too late to inflationary pressures, while others warned about the risks of too excessive monetary tightening. Reflecting these two views, we consider two alternative scenarios for monetary policy relative to our baseline policy rule. While in one of them monetary policy reacts more strongly to deviations from its inflation target ("stricter inflation targeting"), in the other the central bank is more accommodative, not responding immediately to inflationary pressures ("delayed response").

As we can see on Graph I.3, the results depend crucially on these policy settings. A more aggressive monetary tightening constrains aggregate demand via higher real interest rates, leading to lower GDP growth and inflation. This entails a larger decline in the primary balance, while a more "hawkish" monetary stance also raises the effective interest rate on public debt, directly pushing up interest payments. All of these factors contribute to raising the debt-to-GDP ratio above its baseline trajectory.

In contrast, with an initially unresponsive monetary policy the opposite happens, and results even change in qualitative terms, leading to an outright *fall* in public debt as a share of GDP. A more "dovish" monetary stance supports aggregate demand and real growth, and thereby also facilitates stronger domestic price pressures via second round effects, encouraging workers to try to recover more of their lost purchasing power via faster growing nominal wages. A more gradual monetary tightening also lowers the effective nominal interest rate on public debt, directly helping to keep interest payments in check. Together with higher inflation, this leads to a markedly negative effective *real* interest rate on bonds: the implicit fiscal consolidation behind the debt reduction is essentially paid for by levying an inflation tax on long term bondholders. That said, the response of the primary budget balance also flips sign and contributes to lower public debt. The main reasons behind this are that higher real GDP lowers the GDP share of expenditure items that are fixed in real terms (like transfers), and also that higher nominal wage growth increases the average labour tax rate in a progressive tax system due to the fiscal drag effect. This highlights the fact that in addition to leading to higher inflation (with its own welfare costs), this policy does not provide a free lunch in a narrower sense either, as debt reduction is essentially paid for by households ([16]).

This more accommodative scenario bears some resemblance to a *passive monetary policy* regime ([17]), whereby the central bank is not (very) responsive to inflationary pressures and the policy rule violates the Taylor principle, meaning that it raises interest rates less than one-for-one to rising inflation. This entails a drop in short term *ex post* real interest rates, such that inflation has the potential to stabilise

([16]) The delayed response strategy might also run the risk of de-anchoring inflation expectations, which would require more costly higher interest rates later on. This channel is present in our model only to the extent that inflation expectations are partially backward-looking, not fully anticipating future monetary policy actions.

([17]) Leeper, E. M. (1991). Equilibria Under “active” and “passive” monetary and fiscal policies. *Journal of Monetary Economics*, 27, 129–147.

even short term debt at the expense of bondholders. In contrast, recall that in our baseline scenario an *active monetary policy* (satisfying the Taylor principle) ensures to raise *short term* real interest rates, and the *effective* real interest rate for government debt can decline only due to long debt maturities: short-term debt could not be inflated away under such a regime, and rather taxpayers would have to raise primary budget surpluses in the future to stabilise public debt (passive fiscal policy).

That said, monetary policy remains ultimately active in all our simulations ([18]), but the "delayed response" scenario *temporarily* suspends the Taylor-principle by keeping the policy rate completely unresponsive for 5 quarters, bringing in some of the features of a passive monetary policy regime.

Turning to the role of debt maturities, the rather long weighted average maturity of outstanding government bonds might be a misleading indicator. The main reason for this is that past bond purchases by central banks (quantitative easing or QE) have shortened the duration of the *consolidated* government's liabilities (i.e. those of central banks and treasuries combined) ([19]). QE effectively swapped long-term government liabilities (bonds) for very short-term monetary liabilities (central bank reserves) in the hands of the private sector: while these long bonds still count towards average debt maturity indicators, they have in effect been bought back by the consolidated government, which issued very short-term liabilities in their stead. Another way to see how rising short term interest rates can impact the fiscal balance sooner than suggested by bond maturities, is to consider that QE has created a big maturity mismatch in the central bank's balance sheet, financing long assets with short liabilities. So as policy rates go up, this immediately leads to losses for taxpayer-owned central banks via rising interest costs on their short reserves, and thereby lowering seigniorage revenue for the government budget (or even requiring explicit recapitalisation from the treasury).

Therefore, the fiscal costs of monetary tightening via raising short term interest rates might materialise sooner than suggested by general government debt maturities, once we take into account the effect of past QE programs. While the central bank balance sheet is not modelled explicitly in QUEST, we can think of public debt in the model as that of the *consolidated* government (i.e. central bank and treasury combined) – instead of restricting it to *gross general* government debt. In other words, it is a kind of synthetic liability, a portfolio of long treasury bonds and short central bank reserves in the hands of the private sector. This motivates the alternative scenario with a shorter debt maturity of 2 years (instead of 7 years in the baseline case), that would thereby implicitly take into account the rising interest costs on central bank reserves ([20]).

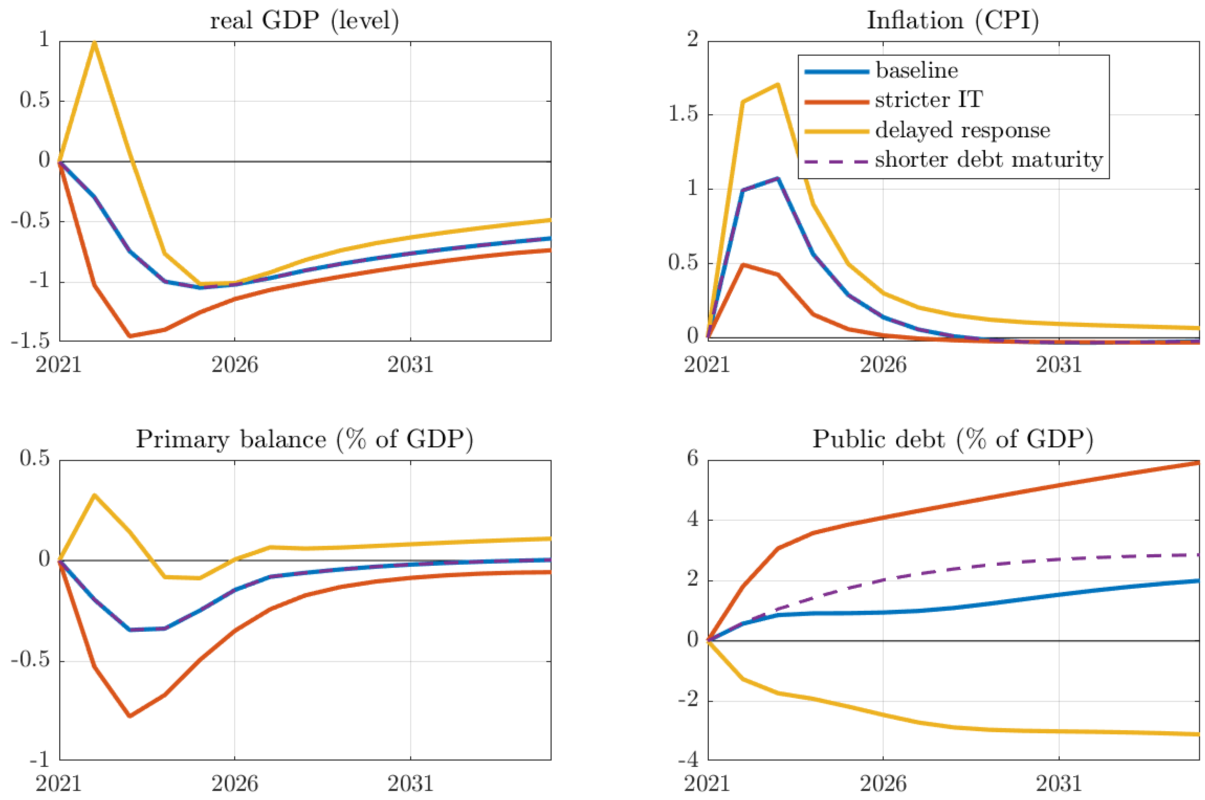
As shown on Graph I.3, shorter debt maturity would speed up the rise in debt-to-GDP ratios, as higher short-term rates would feed much quicker into effective debt financing costs. However, when the debt stabilisation motive in the fiscal rule is switched off (as is the case in the first 20 years of our simulation), this does not affect the primary budget balance, only interest payments. Therefore, without additional fiscal impulse, maturity length does not matter much for the wider macroeconomic effect of the shock either – but it is quite consequential for debt dynamics.

([18]) This is a necessary feature to pin down the price level and have a unique determinate equilibrium in the presence of an ultimately Ricardian passive fiscal rule that stabilises public debt via raising primary budget surpluses (in our scenarios the fiscal rule is switched on only after 20 years though).

([19]) Another reason is that average maturity is biased upwards by a few very long maturity bonds, such that the median ("interest-rate half life") is much shorter, which means that near term financing costs could increase faster than expected. *The Economist.* (2022). How higher interest rates will squeeze government budgets. 12 July 2022, https://www.economist.com/finance-and-economics/2022/07/12/how-higher-interest-rates-will-squeeze-government-budgets.

([20]) As a consequence of this modelling shortcut, the profit/loss of central banks is captured among debt service costs of the consolidated government instead of in the general government's primary balance. But apart from this, it should capture overall fiscal costs accurately.

Graph I.3: **Effects of an adverse terms-of-trade shock under alternative monetary policy settings**



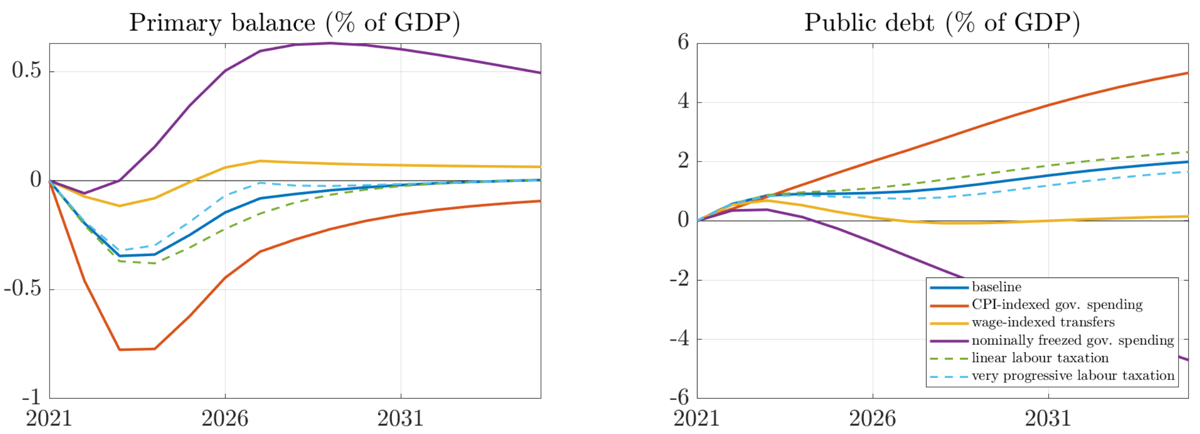
Impulse responses to a series of unexpected adverse terms-of-trade shocks, simulated by a version of the QUEST model, for the EU-27. The alternative scenario “stricter inflation targeting” features a Taylor rule with an inflation reaction coefficient of 3 instead of 1.2 in the baseline scenario. In the “delayed response” scenario monetary policy keeps interest rates fixed for the first 5 quarters following the shock. “Shorter debt maturity” features an average debt maturity of 2 years instead of 7.

Source: European Commission staff calculations.

To put this another way, by shortening the maturity of the consolidated government’s debt vis-a-vis the private sector, QE has also limited the government's ability to erode the real value of its outstanding liabilities by surprise inflation (i.e. its capacity to "inflate away"). Those shortened liabilities are being repriced more quickly at the higher nominal interest rates brought about by rising inflation, thereby offsetting the beneficial effect of higher inflation within the snowball term to a larger extent (i.e. limiting to how low the ex post real effective government interest rate can fall) ([21]).

([21]) Of course, the central bank (a sub-branch of the government) could decide *not* to raise short-term nominal interest rates in response to rising inflation, thereby ensuring that real rates are falling for whatever maturities (a passive monetary policy rule, violating the Taylor principle). That is, coordinated joint monetary-fiscal policies always have the power to inflate away their paper liabilities, even if they have very short maturities. The delayed monetary response scenario discussed above goes some way towards such a policy mix, but only to a limited extent. A truly permanent passive monetary + active fiscal policy regime, however, is not considered in this paper.

Graph I.4: **Effects of an adverse terms-of-trade shock under alternative fiscal policy settings**



Impulse responses to a series of adverse terms-of-trade shocks, simulated by a version of the QUEST model, for the EU-27.

Source: European Commission staff calculations.

I.4.2. Fiscal policy

Recall that the baseline result of a widening primary deficit after a terms-of-trade deterioration was mainly driven by the assumption of transfers being indexed to rising consumer prices. To investigate the robustness of this result, we also explore alternative indexation assumptions concerning public expenditures like government consumption and investment (assumed to be fixed as a share of GDP in the baseline scenario), and transfers (assumed to be indexed to CPI in the baseline).

As we can see on Graph I.4, indexing government consumption and investment (beyond transfers) to rising CPI, amid falling real domestic income, raises the primary deficit and public debt further relative to the baseline scenario – despite also contributing to somewhat higher real growth and inflation. In contrast, freezing all these expenditure items in nominal terms eventually eases the pressure on public finances, as they become eroded as a share of a higher nominal GDP. The burden of this fiscal adjustment would be born by the recipients of these expenditures (e.g. pensioners and civil servants), who would see their real disposable income decline further. This scenario provides an illustration of a significant “benefit erosion”, whereby government expenditures fail to keep up with inflation ([22]). Finally, indexing transfers to nominal wages is in between these two extreme scenarios. Relative to the baseline, where transfers are indexed to CPI, this assumption leads to higher primary balances and more stable debt dynamics, since nominal wages grow less than CPI inflation (i.e. CPI-deflated real wages are falling).

The main takeaway from this exercise is that different expenditure indexation rules are highly consequential for debt dynamics. However, our baseline result that the debt-to-GDP ratio increases after an adverse terms-of-trade shock, seems fairly robust across most of these stylised scenarios. That said, to the extent that actual policy on the very short run is better characterised by non-immediate indexation, debt dynamics on this horizon might be described more accurately by our stylised scenario of a complete nominal freeze on public expenditures, where the associated benefit erosion could contribute to lower debt-to-GDP.

([22]) Note however that the primary balance initially declines even under this benefit erosion scenario, due to a temporarily declining nominal GDP. This is because right after the ToT shock, in addition to declining real GDP, the GDP deflator temporarily falls. As explained in Section I.2.2., this is due to the only gradually developing second round price pressures, whereby imperfect pass-through of more expensive imported inputs to gross output prices, as well as the downward pressure on domestic prices stemming from weaker demand initially dominate the attempt of domestic workers and firms to recover their (CPI-deflated) real income losses. The GDP deflator starts to increase only later under our baseline monetary policy settings.

We also consider alternative fiscal settings on the revenue side. Recall that in our baseline scenario with a progressive labour tax system, the fiscal drag effect contributes to higher tax revenues and supports the primary balance (as the wage distribution shifts into higher, nominally fixed tax brackets, raising the average labour tax rate). In contrast to this baseline scenario, under a linear labour tax system (or in a progressive tax system where tax brackets are adjusted in real time with wage inflation), this fiscal drag effect is missing, whereas under an even more progressive tax system it is stronger. While this has some impact on households' disposable income, as Graph I.4 shows, in terms of debt dynamics it makes a much smaller quantitative difference than varying expenditure-indexation rules ([23]).

I.5. DIFFERENT INFLATIONARY SHOCKS

In order to highlight the importance of the underlying source of inflation, we consider an illustrative exercise with a positive demand shock. Despite having similar inflationary consequences, such a shock entails starkly different macroeconomic and fiscal implications. In fact, a positive demand shock, with the *same* inflationary impact as the adverse ToT shock, would have qualitatively opposite fiscal effects (see Graph I.5) ([24]). In this case, rising CPI inflation goes together with higher real GDP as well as an even faster-increasing GDP-deflator (due to the domestic source of inflation). As a result, the primary balance rises which, combined with beneficial snowball effects stemming mainly from higher nominal growth, pulls down the debt-to-GDP ratio ([25]).

Graph I.5 also displays the effects of rising firm markups, i.e. a negative supply shock that originates from the *domestic* economy. This has qualitatively similar fiscal implications as the adverse terms-of-trade shock (that originates from *abroad*), mainly due to depressing real output while also pushing inflation upwards, and inviting monetary tightening. However, the domestic (as opposed to external) origins of the supply shock make a difference for the time profile and transmission channels of the effects. In particular, the evolution of the wedge between CPI and GDP-deflator and the strength of second round effects are quite different: the beneficial expenditure switching effects of a terms-of-trade deterioration are missing for the domestic supply shock, leading to an initially deeper fall in real GDP. But domestic prices (and thereby nominal GDP) initially rise more given the domestic trigger for inflation, after which they moderate more quickly as a directly suppressed labour share and larger labour market slack keep subsequent second round effects more in check. This makes for an initially smaller, but eventually larger rise in public debt compared to the terms-of-trade shock.

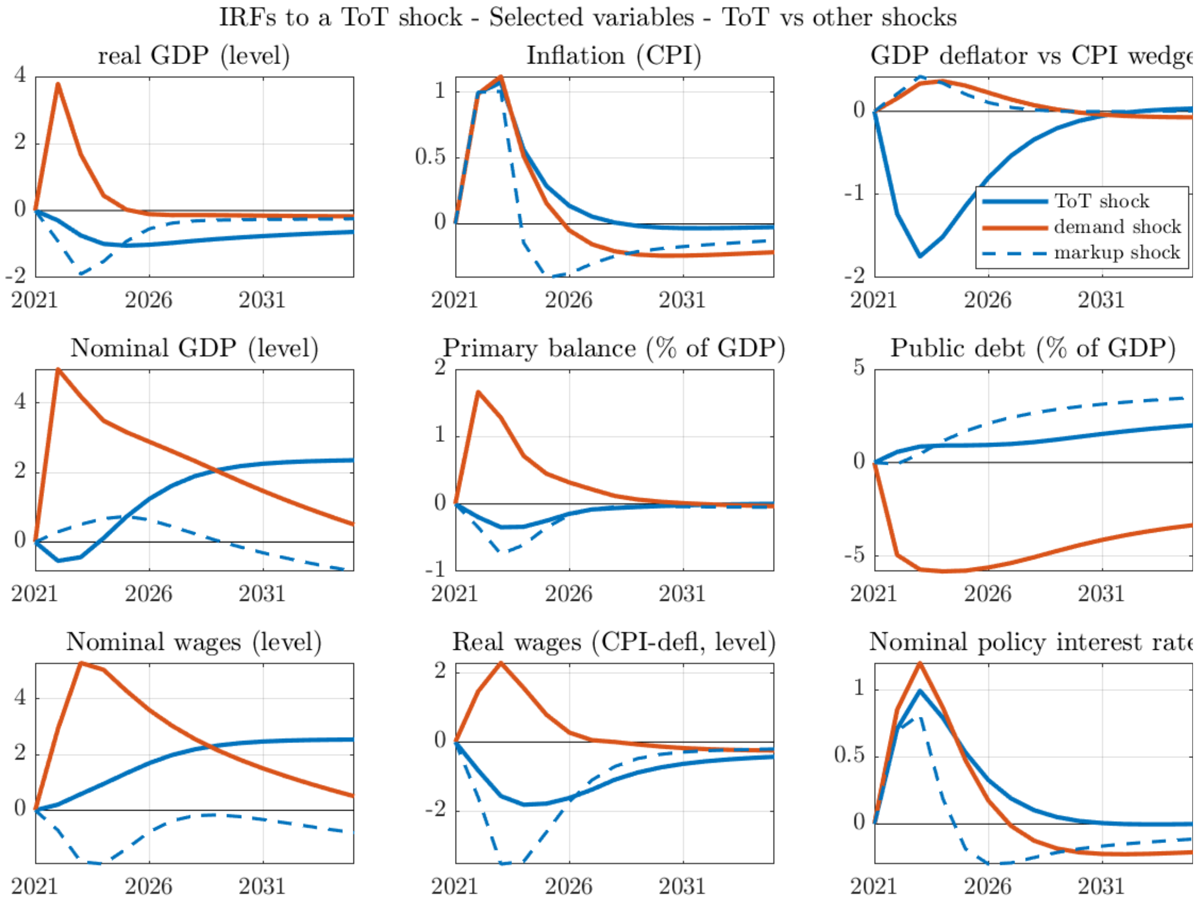
Inflation in Europe is likely driven by a combination of different types of shocks, so the relevant fiscal effects are most probably a mix of the clean scenarios discussed here. That said, the simulations presented here emphasise the importance of identifying the underlying sources of inflation for properly estimating the fiscal consequences.

([23]) This is also due to the only gradual development of second-round effects. The fiscal drag phenomenon relies on fast-increasing nominal wages. However, as second-round effects develop only gradually, the increase in nominal wages is not as strong in the beginning, and would only contribute noticeably to the fiscal drag later on, by which time the tax brackets are likely to be adjusted. In our simulations, they are fixed for 5 years.

([24]) Similar conclusions are reached by Bankowski, Krzysztof, Othman Bouabdallah, Cristina Checherita-Westphal, Maximilian Freier, Pascal Jacquinot, and Philip Muggenthaler. 2023. "Fiscal policy and high inflation." *ECB Economic Bulletin*, 2023(2), url. https://www.ecb.europa.eu/pub/economic-bulletin/articles/2023/html/ecb.ebart202302_01~2bd46eff8f.en.html.

([25]) Note that the central bank raises nominal interest rates similarly, given the similar inflationary impact. For a demand shock there's some additional monetary tightening initially, responding to stronger real output, but it is not sufficient to offset the larger increase in higher nominal growth within the snowball effects.

Graph I.5: **The effects of different types of shocks**



Impulse responses to various shocks based on simulations by the QUEST model for the EU-27. All shocks are calibrated such that CPI inflation in the first year following the shock rises by 1 percentage points relative to the steady state.

Source: European Commission staff calculations.

While the intuition behind the advantageous effects of higher inflation on public finances is not necessarily wrong (as in the case of a positive demand shock), the takeaway is that not *all* types of inflationary shocks are necessarily beneficial for debt-sustainability. In particular, despite raising inflation, a deteriorating terms-of-trade offers little scope for "inflating away" public debt.

I.6. CONCLUDING REMARKS

This chapter investigated the general equilibrium fiscal implications of an adverse terms-of-trade shock. Despite the inflationary nature of such a shock, debt-to-GDP ratios tend to rise, as negative real growth effects due to a loss of domestic purchasing power and widening budget deficits offset the erosive effect of higher inflation, especially if monetary policy raises interest rates promptly and debt has short maturities.

That said, the simulations have also demonstrated how consequential policy settings can be. Under certain policy configurations public debt can indeed follow a lower trajectory, but this comes with some trade-offs and such alternative policies are no free lunch. The burden of the implicit fiscal consolidation behind stabilising the debt-to-GDP ratio is always born by some domestic agents, be it transfer-recipients (with nominally frozen public expenditures) or long-term bondholders (when monetary policy tolerates higher inflation). In other words, the terms-of-trade shock makes the economy as a whole worse off, by lowering real gross domestic income, so it has an inherently detrimental effect – public finances can benefit from this situation only to the extent that some other sector of the economy pays for it. On top of this, the higher inflation path or higher unemployment and lower degree of fiscal income insurance associated with these policies might entail further welfare costs on their own right.

It is worth emphasising that, rather than deriving *optimal* policies along these complex trade-offs, the analysis in this chapter is strictly descriptive. It does not aim to suggest that rising debt ratios in the face of an adverse shock are undesirable from a normative aspect, nor that more inflationary monetary policies or more austere budgetary consolidation would be called for, just so that debt-to-GDP does not increase as much. In fact, far from being unambiguously bad, public debt can be a very useful tool in the hands of fiscal policy if it is not overused ([26]).

([26]) As Blanchard and Pisani-Ferry (2022) pointed out, it can be welfare-improving if fiscal policy fulfils an insurance role and supports the groups most exposed to real income losses amid the cost-of-living crisis – while monetary policy aims to keep second round domestic price pressures in check, without trying to suppress all of the first round impact. Blanchard, O., & Pisani-Ferry, J. (2022). Fiscal support and monetary vigilance: Economic policy implications of the Russia-Ukraine war for the European Union. *PIIE Policy Brief*, 2022(5). https://www.piie.com/sites/default/files/documents/pb22-5.pdf.

II. CLIMATE CHANGE AND ITS IMPACT ON PRICES AND INFLATION

By Christian Buelens [27]

Abstract: *As inflation in the euro area and beyond falls from its multi-decade highs of 2022, the focus is now turning to the potentially inflationary impact of ongoing rapid structural transformation. Climate change is transforming the planet in ways that have become ever more disruptive and life-threatening in many parts of the world. As global greenhouse gas emissions continue to grow, amid slow and insufficient mitigation efforts, its impact will become even stronger in the years ahead. This article discusses how prices and inflation will be affected by climate change and efforts to mitigate it and adapt to it. It highlights how relative price adjustments will play a key role in this process. These adjustments may be due to climate-induced shocks to productions factors or preferences, or to some of the policy instruments used. Both climate change and mitigation measures are expected to impact a wide array of prices, particularly food and energy prices. While there is substantial uncertainty about orders of magnitude, inflation is expected to become more volatile and subject to upward pressure. Inflation volatility over time will largely depend on adaptation and mitigation efforts. Overall, inflation is likely to become harder to interpret and forecast. This may in turn affect inflation expectations and create more uncertainty in macroeconomic policymaking.*

Inflation in the euro area and beyond has been severely disrupted by a series of unprecedented global shocks since the outbreak of the COVID-19 pandemic in early 2020. These shocks have pushed inflation to multi-decade highs across the world. As these shocks wane and inflation comes down, the focus is now turning to the inflationary impact of ongoing structural transformations, such as climate change. Unlike the COVID-19 pandemic, climate change is not a sudden shock or single event, but a process that has been building up for decades and that has become ever more disruptive and life-threatening across many parts of the world. As it accelerates, its impact will become even stronger in the years ahead. This article discusses what climate change – and endeavours to mitigate it or adapt to it – may mean for prices and inflation.

II.1. CLIMATE CHANGE: WHERE DO WE STAND?

The global climate is changing dramatically due to human activity. As the Intergovernmental Panel on Climate Change (IPCC) concluded in 2021 ([28]), ['It] is unequivocal that human influence has warmed the atmosphere, ocean and land'. In 2023, the global mean surface temperature in 2023 was 1.48°C above the pre-industrial (1850–1900) average, extending the accelerating upward trend observed since the 1970s (Graph II.1, panel A) ([29]). During that period, Europe has been the fastest-warming continent ([30]). Daily sea surface temperatures both confirm the steady increase in temperatures over time and further expose the daunting temperature leap in 2023, with record highs on a daily basis since (Graph II.1, panel

([27]) I wish to thank Leonor Coutinho, Quentin Dupriez, Asa Johannesson, Jakob Mainka, Arnaud Mercier, Philipp Pfeiffer, Eric Ruscher and Magdalena Spooner for useful comments and discussions. All errors and views expressed in this article are mine and should not be attributed to the European Commission.

([28]) Intergovernmental Panel on Climate Change (IPCC), 2021: Summary for Policymakers. In: AR6 Climate Change 2021: The Physical Science Basis, https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM_final.pdf.

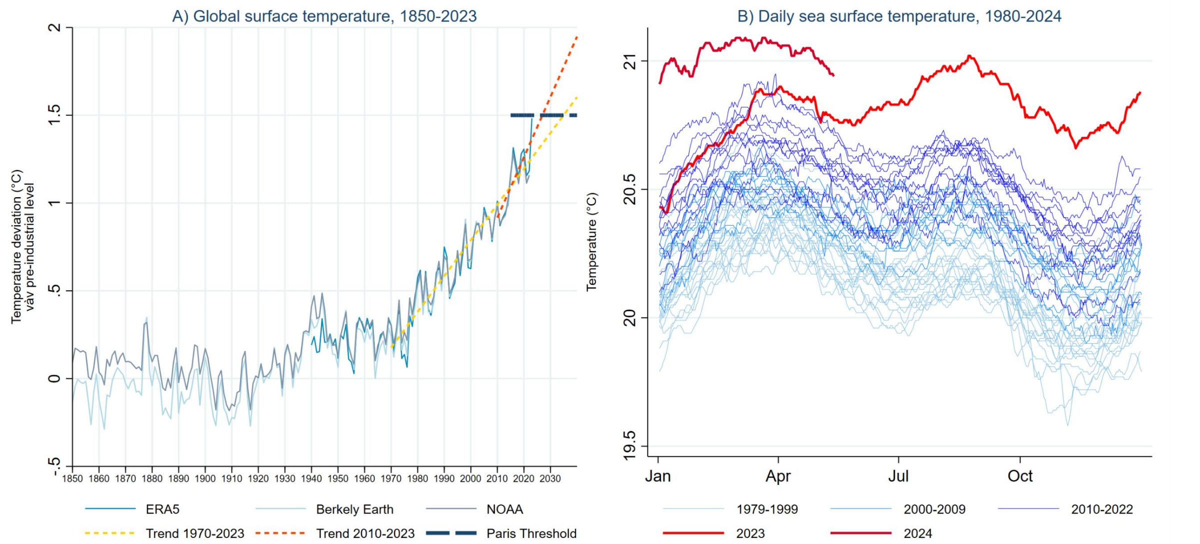
([29]) The average annual temperature increase between 1970 and 2023 has been 0.020 C. Over the period 2010-2023 the average annual temperature increase rose to 0.034 C.

([30]) Copernicus Climate Change Service (C3S), 2024, European State of the Climate Report 2023.

B) (31). While rising average temperatures are a key indicator of climate change, the IPCC has also identified a series of widespread and rapid changes in the atmosphere, ocean, cryosphere (polar ice caps) and biosphere, which become larger as global warming increases (i.e. impacts are non-linear), as well as weather and climate extremes, such as heatwaves, heavy precipitation or droughts.

Climate change can be clearly attributed to human influence and economic activity (see Box II.1). Global annual greenhouse gases (GHGs) have been emitted at successive annual record levels, although there were brief respites after the global financial crisis in 2009 and in 2020, the first year of the COVID-19 pandemic (Graph II.2, panel A). The growth in GHG emissions is now mainly driven by emerging market economies, which, however, started from a lower basis, and emit less per capita than advanced economies. Meanwhile, GHG emissions by advanced economies, such as the EU or the USA, have been contracting. New emissions expand the large stock (32) of GHGs already accumulated in the atmosphere, which trap heat and cause global temperatures to rise. As GHGs mix in the atmosphere, regardless of their geographic origin, they present a global problem. Addressing it is complex, as the contribution to the GHG stock and the consequences of climate change are often very uneven across regions. This means that incentives to find collective solutions may not always be aligned. Cumulative GHG emissions since 1970 (Graph II.2, panel B) show that regional shares of annual emissions and stock vary. For instance, the EU's and the USA's contributions to the GHG stock are significantly higher than their contributions to annual emissions. Focusing on the EU, annual emissions have declined across all sectors, except for transport, where emissions have continued to increase (Graph II.2, panel C). The main emitters are the power, transport and housing sectors.

Graph II.1: **Global temperature trends**



Notes: ERA5, Berkely Earth and NOAA are different global datasets. The pre-industrial level refers to the period 1850-1900. Last observation in panel B: 13 May 2024.

Source: ERA5, Copernicus Climate Change Service.

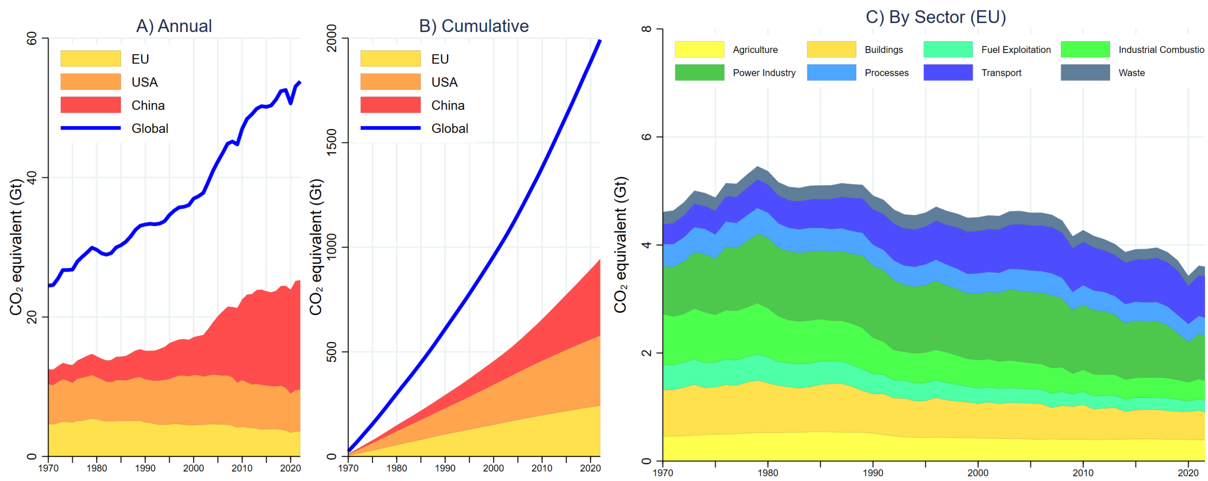
Past and future GHG emissions mean that many aspects of climate change are irreversible (IPCC 2021), even in the most optimistic scenarios. This irreversibility requires global society to adapt to a changing

(31) While the El Niño event is an important factor behind the high temperatures in late 2023 and early 2024, there have been 12 other El Niño episodes in the sample shown.

(32) While there is some decay in GHGs, this tends to be very slow and differs depending on the GHG.

climate (*climate change adaptation*) (33). However, it is important to recognise that there are physical limits to adaptation and that adverse scenarios, including those that breach climate tipping points, would likely exceed such limits. Given the potentially limitless nature of global warming, actions to limit greenhouse gas emissions – by transitioning to a low-carbon economy – are therefore more necessary than ever to contain climate change (*climate change mitigation*) (34). The future emission pathways will continue to condition the extent of climate change. The IPCC (2021) has warned that without deep reductions in GHG emissions in the coming decades, the global warming thresholds of +1.5 °C and +2 °C set in the 2015 Paris Agreement, will be exceeded in the 21st century. If the average temperature increases of recent decades were to persist (Graph II.1, panel A), the +1.5 °C threshold would be breached within the next decade.

Graph II.2: **Global greenhouse gas emissions, 1970-2022**



Note: GHG emissions include CO2 (fossil only), CH4, N2O and F-gases.

Source: European Commission, Joint Research Centre (JRC), EDGAR (Emissions Database for Global Atmospheric Research) Community GHG database.

Climate change represents a grave threat to life and livelihoods and has already inflicted severe damage in the form of human and economic losses. The aggregate macroeconomic impacts of climate change are clearly negative (Tol, 2018; Kahn et al., 2021) (35) and welfare reducing overall, although they are distributed unevenly across sections of the population, economic sectors, geographic locations and over time. In the EU, economic losses caused by extreme climate events in

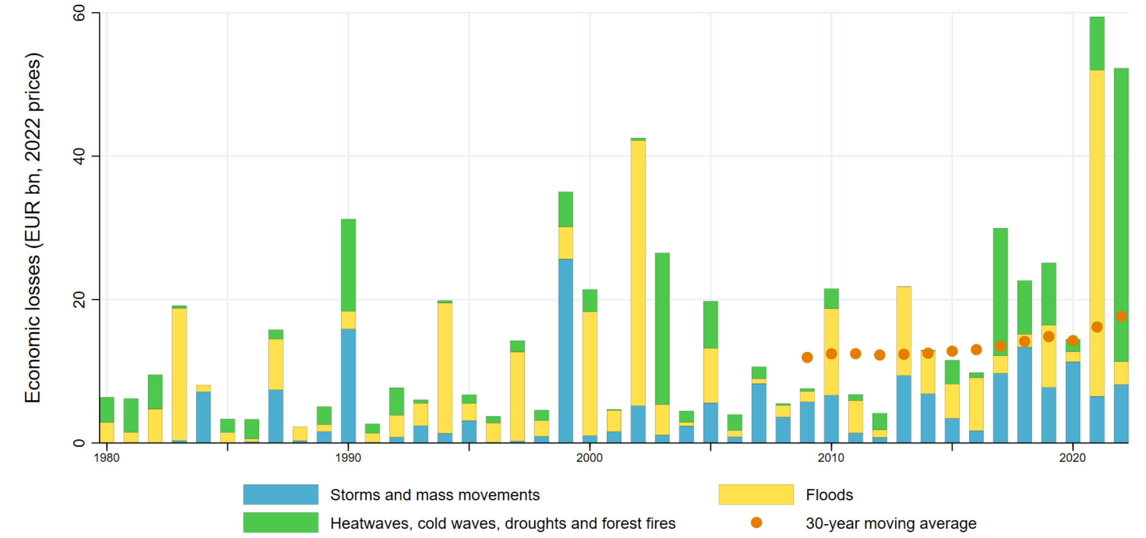
(33) Adaptation means anticipating the adverse effects of climate change and taking appropriate action to prevent or minimise the damage they can cause, or taking advantage of opportunities that may arise. Examples of adaptation measures include large-scale infrastructure changes, such as building defences to protect against sea-level rise, as well as behavioural shifts, such as individuals reducing their food waste. Adaptation measures also include, for instance, urban planning, early warning and response systems, agricultural adaptation (e.g. adoption of sustainable farming practices), sustainable water management or rehabilitation of ecosystems. In essence, adaptation can be understood as the process of adjusting to the current and future effects of climate change (based on definition provided by the European Environment Agency).

(34) Mitigation means making the impacts of climate change less severe by preventing or reducing the emission of greenhouse gases (GHG) into the atmosphere. Mitigation is achieved either by reducing the sources of these gases - e.g., by increasing the share of renewable energies, or establishing a cleaner mobility system - or by enhancing the storage of these gases - e.g., by increasing the size of forests. In short, mitigation is a human intervention that reduces the sources of GHG emissions and/or enhances the sinks (definition provided by the European Environment Agency).

(35) Tol, 2018, The Economic Impacts of Climate Change, Review of Environmental Economics and Policy, volume 12, issue 1, Winter 2018, pp. 4-25; Kahn, Mohaddes, Ng, Pesaran, Raissi and Yang, 2021, Long-term macroeconomic effects of climate change: A cross-country analysis, Energy Economics, Volume 104, 2021.

2021 and 2022 are estimated at EUR 59 bn and EUR 52 bn, respectively (Graph II.3), broadly equivalent to the GDP of Slovenia. The trend is clear: aggregate economic losses are rising. Their cause, however, varies: while the bulk of damage in 2021 was caused by floods, in 2022 (and 2023) it was due mainly to heat, droughts and wildfires. Historical GHG emissions and socio-economic inertia imply that future economic damages are unavoidable. Kotz et al. (2024) ([36]) project sub-national damages from average temperature increases and higher variability in temperatures and precipitation. Their estimates suggest that the world economy is committed to an income reduction of 19% by 2049 (relative to a baseline without climate impacts), independent of future emission choices. Future emission trajectories however matter for projected damages at longer horizons, with high emission pathways leading to greater damage.

Graph II.3: **Economic losses caused by weather- and climate-related extreme events in the EU, 1980-2022**



Source: European Environment Agency.

With rapidly increasing risks and society's failure to adequately prepare, damage is bound to rise in the future. In its 2024 European Climate Risk Assessment ([37]), the European Environmental Agency (EEA) concludes that out of 36 major climate risks, 21 urgently require more adaptation policies and actions, particularly given the long lead times for such policies and actions. The EEA also points to regional disparities, with southern Europe, low-lying coastal regions and the outermost regions of the EU being most exposed to multiple climate risks.

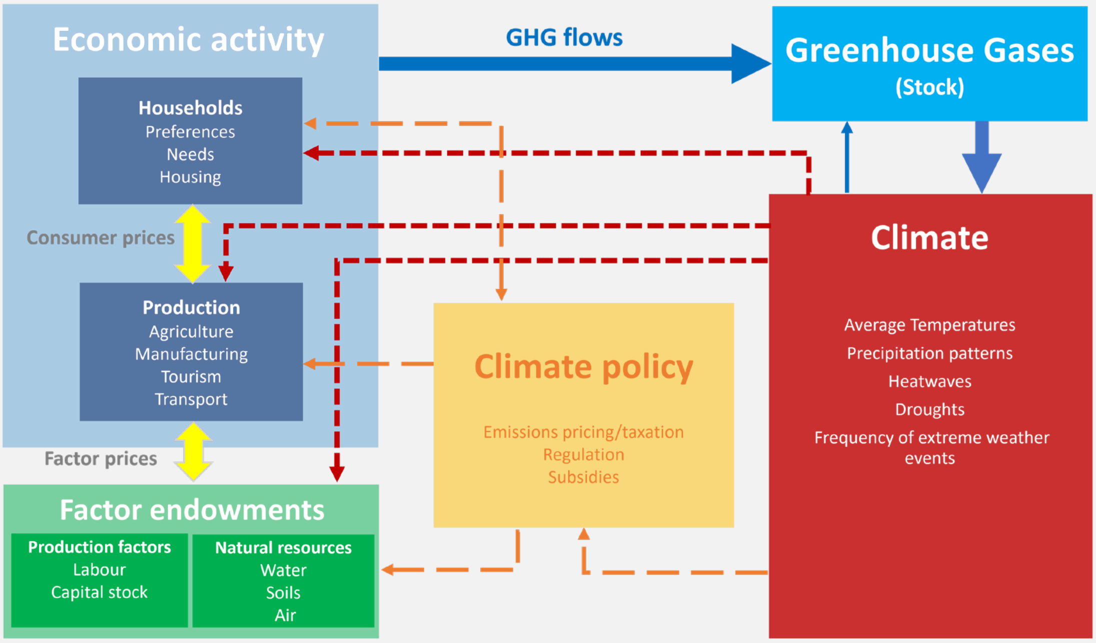
([36]) Kotz, Levermann and Wenz, 2024, The economic commitment of climate change. Nature 628, 551–557 (2024).

([37]) European Environmental Agency, 2024, European climate risk assessment.

Box II.1: Interactions between the economy and the climate

The diagram below shows the two-way interactions between economic activity and the climate. The blue arrows show the impact of economic activity, i.e. ways of living and producing, on the climate. Economic activity is determined by household preferences and needs, and businesses' (technology) choices. It is conditional upon on production factors (labour, capital stock) and natural resources at a given point in time, which combine to generate the output that is then consumed by households or added to the capital stock. During the production process, greenhouse gases (GHGs) are emitted that add to the GHG stock already present in the atmosphere. The accumulation of GHGs impacts the climate in various ways, affecting average temperatures, precipitation patterns and the frequency of extreme weather events, such as draughts, for example.

Graph 1: **Interaction between economic activity and the climate**



Note: This diagram shows the two-way interactions between economic activity and the climate. Blue arrows show how human activity affects the climate, while red arrows show how climate change affects human and economic activity. Grey arrows relate to the formation of factor and consumer prices. Orange arrows show drivers of climate policies and the interactions between those policies and the economy (e.g. compliance costs).

The red arrows show the impact of the climate on the economy. There are multiple transmission channels through which the climate impacts economic activity. They can be direct or indirect, physical or non-physical, sudden (frequency of events) or progressive (warming), etc. (This list is not exhaustive).

1. The climate influences some of the characteristics and effective availability of production factors and natural resources. A change in the climate may, for example, impoverish or deplete natural resources, e.g. lower soil fertility or disrupt the water cycle, or it may lead to a more rapid depreciation or destruction of built infrastructure and housing. Likewise, climate change is also expected to directly impact the productivity of labour. A reduction in effective factor endowments and resources will constrain the production process and reduce (potential) output.

2. The climate also has a direct effect on output produced. Examples include the destruction of production, such as crops, or the unavailability of goods due to transport bottlenecks caused by extreme weather events, which are becoming more frequent.

(Continued on the next page)

Box (continued)

3. The climate affects household preferences and human needs (e.g. cooling or warming) and by extension drives demand.

4. Finally, changes in the climate can have self-reinforcing effects, for example heatwaves that lead to wildfires and in turn to GHG releases (represented by a blue arrow).

Left to itself, the system depicted is a closed loop, whereby human and economic activity in the present period, through its effect on the climate, negatively affects human and economic activity in the future. This will also affect the formation prices of production factors and consumer items, represented by the grey arrows and discussed further in Box II.2 and Section II.2.

Breaking – or at least attenuating – this loop hence requires curbing new GHG emissions, and adapting economic activity to shield it as much as possible from the adverse impacts from the existing GHG stock. Climate policies attempt to achieve this. The intensity of those policies in turn hinges on whether governments and societies have the resolve and ability to act, which is likely to depend greatly on the observed, rather than only on the projected extent of climate change. It is also subject to political economy constraints (due to the time lag between emissions and their effects) and global policy coordination challenges. Putting a price on GHG emissions plays a key role in climate change mitigation, as discussed in Box II.3 and Section II.3, and affects production costs and thus prices.

II.2. THE IMPACT OF CLIMATE CHANGE EXPOSURE ON INFLATION

This section discusses how climate change affects prices and inflation. The gradual rise of temperatures, or more frequent extreme weather events, can hit the economy either as supply shocks (e.g. reduced productive capacity) or demand shocks (e.g. declining wealth and confidence), with potentially opposing effects on the general price level. The diversity of climate events and risks means both that many different types of goods and services could be impacted, and that different climate change-induced events will impact individual goods unevenly, causing volatility both in nominal and relative prices (see Box II.2).

Global warming affects all production factors. Temperatures above certain thresholds may reduce working hours, labour productivity and increase heat stress, in particular for outdoor work (e.g. agriculture, construction), but also in indoor settings (e.g. factories or offices) if temperature levels cannot be regulated well. ([38]) Meanwhile, the diminution in productive capital may occur through capital damage or faster depreciation of built material, notably infrastructure and housing. Losses in economic productivity have been shown to be non-linear in temperature, i.e. the productivity fall for a given increase in temperature will bigger the higher the initial temperature. ([39]) Warming also disrupts ecosystems and affects natural resources, possibly modifying the water cycle or leading to biodiversity losses.

Extreme weather events generally have a negative impact on short-term output, while their persistence will depend on the type of event (e.g. hurricane versus drought) and the specific context in which it takes

([38]) ILO, 2019, Working on a warmer planet: The impact of heat stress on labour productivity and decent work, International Labour Office – Geneva.

([39]) Burke, Hsiang, and Miguel, 2015, Global non-linear effect of temperature on economic production. Nature 527, 235–239 (2015).

place (e.g. vulnerability of built material at the time of the event). Hsiang and Jina (2014) ([40])distinguish between four types of output recoveries following a natural disaster: i) permanent damage (no recovery scenario); ii) recovery to the pre-disaster state (resilience); iii) 'build back better' (e.g. reconstruction enhances 'climate proofing'); and iv) a 'creative destruction' scenario. Understanding the type and persistence of the impact of shocks, including those caused by climate change, is crucial to assessing an economy's cyclical position and inflation drivers, and by extension to making the economic policy decisions that are based on it. The question whether climate change primarily affects the output level, the growth rate, or both, is again shock-specific, ([41]) but it seems reasonable to consider that both are at risk. The evidence on the long-term output effects of extreme weather events is mixed (see Batten (2018) ([42]) for a review), partly because it hinges significantly on the no-disaster counterfactual used as a benchmark, but also because it varies by country: economies with higher GDP per capita generally seem better equipped to mitigate the impact of the shock in the short-term and to build more resilient structures afterwards.

Given its dependence on the weather and natural resources, the agricultural sector – and with food as its main end product – is very exposed to the impacts of climate change. Gradual temperature increases, shifting weather patterns and extreme weather events affect crop yields and animal husbandry. While single extreme weather events are likely to lower production and raise prices of affected items (e.g. crop destruction), the effects of gradual changes in the climate are more ambiguous and location-specific. Specifically, they depend on how easily production can be adjusted, for example by substituting the crops grown. Overall, global cereal yields are expected to become more volatile, which also raises the probability of simultaneous global failures of major crops, such as maize ([43]).

Changing agricultural production constraints will require consumption patterns to adapt, which may in turn entail relative price fluctuations *among* individual food categories. Climate change is therefore highly sectoral by nature. Indeed, many studies on the impact of climate change on inflation focus primarily on the agricultural sector and food prices. Faccia et al. (2021) ([44]) find that upward temperature anomalies have a swift upward effect on food prices in the short term in a cross-country analysis of 48 advanced and emerging economies. However, the effect is insignificant or even negative in the medium term, which points to negative effects on demand caused by supply disruptions. Focusing on the four largest euro area countries, Ciccarelli et al (2023) ([45]) find that increases in monthly mean temperatures affect seasonal euro area inflation patterns by raising inflation in summer and autumn, and that higher temperature variability significantly raises inflation. The impact is mainly concentrated in food and services (which include tourism) and is stronger in warmer euro area counties. Kabundi et al (2022) ([46]) distinguish by type and intensity of climate shocks and find that droughts tend to push inflation up, because of rising food prices. Meanwhile, floods tend to curb inflation, pointing to a predominance of demand shocks. Likewise, Parker (2018) ([47]) finds that the impact of natural disasters on inflation differs by type of disaster and inflation sub-index. Storms and floods lead to a short-lived upward effect on food price inflation, while earthquakes (which are unrelated to climate change) reduce

([40]) Hsiang and Jina, 2014. The causal effect of environmental catastrophe on long-run economic growth: Evidence from 6,700 cyclones, NBER Working Paper No. 20352.

([41]) Batten et al. (2020) or Kahn et al. (2021).

([42]) Batten, 2018, Climate change and the macro-economy: a critical review, Bank of England Staff Working Paper No. 706.

([43]) It is estimated that the probability of a simultaneous loss in maize yields of 10% or more in the top four maize producers (United States, China, Brazil and Argentina) will increase from virtually zero in 2018 to over 6% with a temperature increase of 2 °C. (Tigchelaar, M., Battisti, D. S., Naylor, R. L. and Ray, D. K. (2018), 'Future warming increases probability of globally synchronised maize production shocks', Proceedings of the National Academy of Sciences, 115(26): pp. 6644–6649.).

([44]) Faccia, Parker, Stracca, 2021, Feeling the heat: extreme temperatures and price stability, ECB Working Paper No 2626.

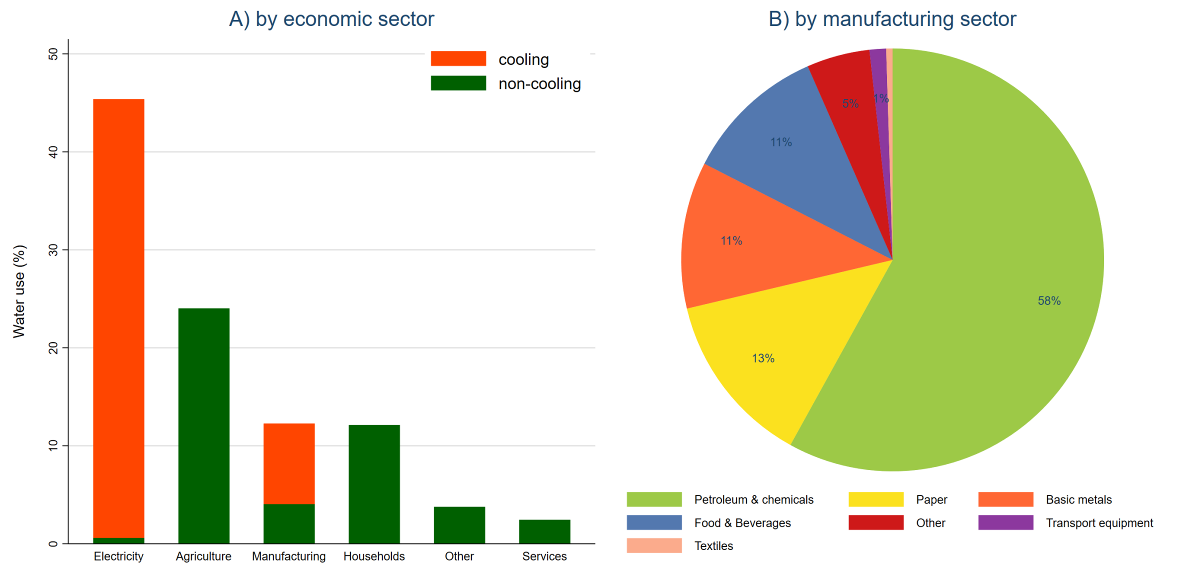
([45]) Ciccarelli, Kuik and Martínez Hernández, 2023, The asymmetric effects of weather shocks on euro area inflation, ECB Working Paper No 2798.

([46]) Kabundi, Mlachila, and Yao, 2022. How Persistent are Climate-Related Price Shocks? Implications for Monetary Policy, IMF Working Paper 22/207.

([47]) Parker, 2018, The Impact of Disasters on Inflation. EconDisCliCha 2, 21–48.

core inflation. While the impact is generally negligible for advanced economies, it can last for several years in developing economies. Peersman (2022) ([48]) estimates that shifts in international food commodity prices between 1961 and 2016, caused by harvest shocks, explain 30% of euro-area inflation volatility. An increase in extreme weather events globally would thus plausibly raise euro area inflation volatility. Analysing both high- and low-income countries, Kotz et al. (2023) ([49]) find that increases in average temperatures have a non-linear and persistent upward effect on inflation, and highlight the risks that climate change poses to price stability.

Graph II.4: **Water use by economic and manufacturing sectors in the EU, 2019**



Note: Water use includes public water supply, and self and other water supply. Due to incomplete data, panel A excludes Ireland, France, Italy, Austria and Finland. Panel B further excludes Greece and Hungary.

Source: Eurostat, own calculations.

The sectoral effects of climate change and disruptive weather events go beyond the agricultural sector, however, and can severely affect many others. This can be illustrated by considering the use of water (excluding precipitation) in various sectors as an example, as climate change is disrupting the water cycle ([50]). As shown in Graph II.4, the electricity sector is the main water user in the EU followed by agriculture and industry. Hence, it is plausible that disruptions to the water cycle, in particular caused by droughts, will have knock-on effects on the prices of goods produced in those sectors. For example, droughts in Taiwan in spring 2021 have compounded pandemic-related shortages of semiconductors, giving a foretaste of how future water stress may impact semiconductor production ([51]). Moreover, with much of the water in the current electricity generation systems and in manufacturing being used for cooling purposes, production efficiency not only depends on the availability of water, but also river temperature. In a case study of Germany, McDermott and Nilsen (2014) ([52]) estimate that electricity

([48]) Peersman, 2020, International food commodity prices and missing (dis)inflation in the euro area, The Review of Economics and Statistics, January 2022, 104(1): 85–100.

([49]) Kotz, Kuik, Lis, and Nickel, 2023. The impact of global warming on inflation: averages, seasonality and extremes, ECB Working Paper 2821.

([50]) Note that disruptions to the water cycle and water availability also depend on non-climate factors, such as water management, land use or pollution.

([51]) Lepawsky, 2024, Climate change induced water stress and future semiconductor supply chain risk. iScience. 2024 Jan 5;27(2):108791.

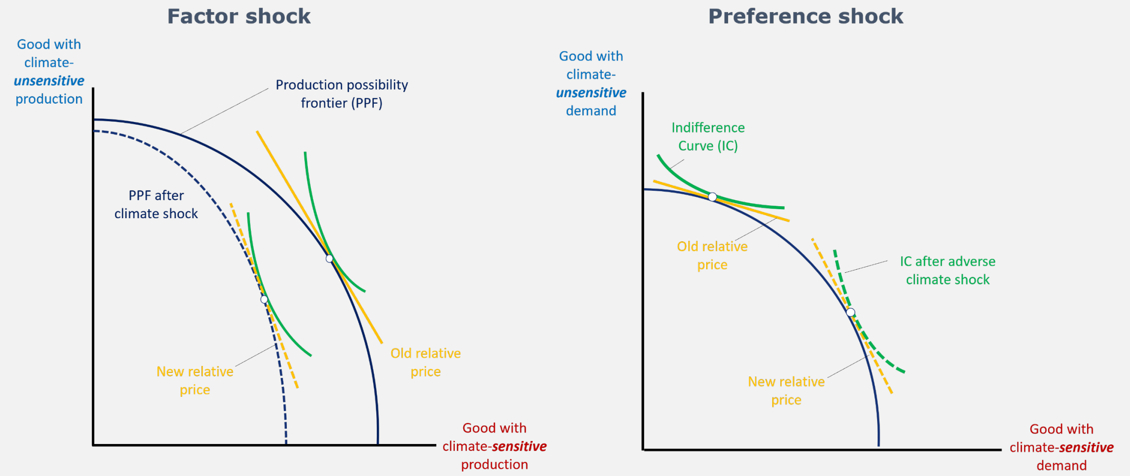
([52]) McDermott and Nilsen, 2014, Electricity Prices, River Temperatures, and Cooling Water Scarcity, Land Economics, February 2014, Vol. 90, No. 1.

Box II.2: **Relative goods and factor prices as adjustment variables to climate change**

Where do prices come in? As illustrated in Box II.1, consumer and factor prices are determined by consumer preferences, choices by firms and endowments. Both preferences and endowments are susceptible to change together with the climate, resulting in adjustments to consumer and factor prices.

The figures below illustrate two major channels though which consumer prices may be affected. The figure on the left shows how an adverse climate supply shock affects production factors. It shows a production possibility frontier (PPF) for two goods, one of which relies heavily on a factor that is sensitive to the climate (such as agriculture, which depends on soil fertility and the water cycle). A negative supply shock (like a drought, flood, hurricane or fire) affects relative factor endowments and entails an inward shift of the PPF. For a given set of (unchanged) preferences, the output of both goods will be lower at the new equilibrium, and consumers will be unambiguously worse off. Relative prices will also change, as the price of the good with the more climate-sensitive production rises relative to the other.

Graph 1: **Relative price shocks**



Note: The figure on the left shows how relative prices change as the effective endowment of a production factor is reduced by a climate shock reduces. The figure on the right shows how relative prices change after individual preferences are changed by a climate shock.

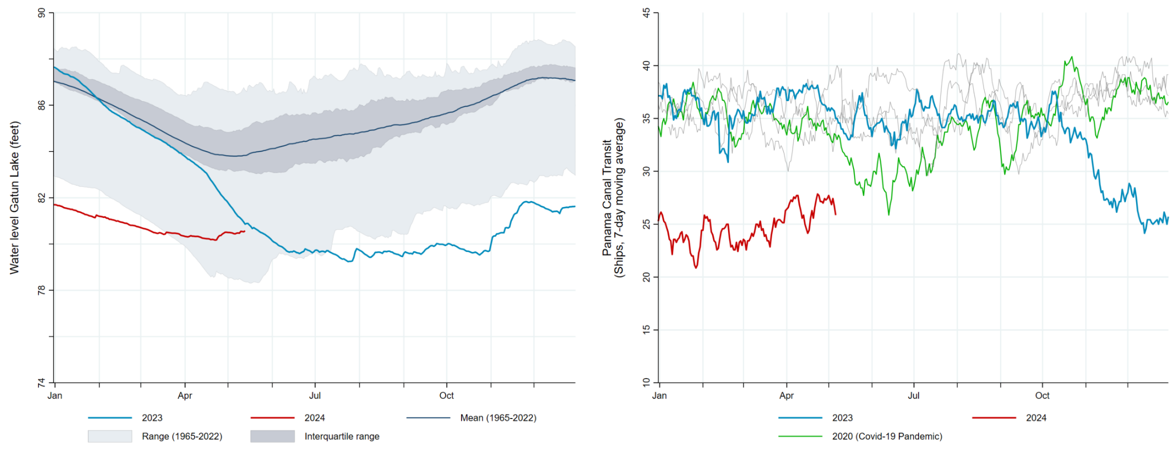
The figure on the right illustrates how prices are affected by a climate-induced preference shock. A preference shock is when the utility derived from the consumption of one good rises as the climate changes (e.g. air conditioners) or when consumers become more conscious of the climate impact of their consumption (e.g. preferring certain transport modes over others). While, in this example, the adverse climate shock leaves the PPF unaffected, it changes the shape of the indifference curves and the composition of demand. The economy will now produce more of the good for which demand is climate-sensitive and less of the other, while the price of the former will rise relative to the latter. Supply and preference shocks can of course conflate, and their effects can either offset or reinforce each other.

prices increase by about 1% per 1% fall in river levels and 1 °C increase in water temperature above 25 °C. Climate related damages are however not limited to economic sectors that intensively rely on natural resources. Floods, for example, do not necessarily affect water-intensive sectors more than other sectors. In a study of the global car industry, Castro-Vincenzi (2024) ([1]) that automotive companies react to floods near their assembly plants by reducing production and partially reallocating it to

([1]) Castro-Vincenzi, 2024, Climate Hazards and Resilience in the Global Car Industry, Working Paper.

unaffected plants within the company. While relocating production allows companies to hedge against local risks, it is accompanied by productivity losses and higher consumer prices.

Graph II.5: **Panama Canal water levels and ship transit**



Note: Last observation: 7 May 2024.

Source: Panama Canal Authority, IMF Portwatch, own calculations.

Beyond its direct effect on production and production sites, water plays a key role for the transport of inputs and final goods. For example, droughts in Europe have resulted in low water levels of rivers in recent years, severely impeding inland waterway transport, either by making it impossible to navigate or requiring lower loads. Likewise, record low water levels in the Gatun Lake since mid-2023 (Graph II.5) ([54]), have led to restrictions in the number and type of vessels allowed to transit the Panama Canal. This has cut ship traffic in one of the world's major maritime thoroughfares by about a third – more than at any time during the Covid-19 pandemic – with adverse implications for trade and supply chains. Besides affecting water abundance, climate change also disrupts transport due to more frequent events such as typhoons, which cause ports to close or obstruct sailing. ([55])

II.3. THE IMPACT OF CLIMATE CHANGE ADAPTATION AND MITIGATION ON INFLATION

The economic consequences of climate change depend on the vulnerability of production and production factors at a given point in time and place. Expected damage can be expressed as the product of the severity of climate change (e.g. probability of extreme events) and economic vulnerability. Future damage can therefore be minimised by reducing the vulnerability and adapt and adjust the economy subject to the constraints imposed by a changing climate. At the same time, these constraints can be rendered less severe by mitigating climate change (discussed below).

([54]) Note that the figure showing water levels in the Gatun Lake, is almost the reverse image of Graph II.1 (panel B) showing daily temperatures pointing to a close relationship.

([55]) Note that while the examples discussed here are restrictive supply shocks, there may be cases where climate change may boost supply, for example melting sea ice opening new trade routes or certain regions becoming more attractive to tourism. However, on balance, the former clearly dominate.

II.3.1. Adapting to climate change

Adapting to climate change is in many ways an exercise in avoiding or limiting future human, natural and material losses. It is necessary due to the unavoidable effects of climate change ([56]) and focuses on the preservation of essential societal and economic functions, but also on the transformation of ecosystems, infrastructure, industry and society. It is all the more important given the irreversibility and faster-than-anticipated speed of many changes observed (e.g. rising temperatures, extinction of species, melting of glaciers). The fact that some climate trends are predictable should in principle help to prevent some future losses. However, the extent of adaptation efforts is ultimately a societal choice that depends in particular on the discounting of future damage and of life in different climate conditions and other political economy considerations. The rapid transformation of climate change, from an abstract and distant prospect to a present-day reality, implies that there is a significant lack of preparedness for present and future climate risks in the EU, as pointed out in the EEA's 2024 climate risk assessment and in the European Commission Communication on Managing Climate Risks (2024), ([57]) which expose a need for greater action, also given the long lead times involved.

While adapting to climate change is costly, the costs of inaction are much larger still. Adaptation has many dimensions. It includes for example efforts to ensure that buildings and infrastructure (roads, bridges, power grids) are resilient to shocks from extreme weather events. This can be achieved through public and private investments, subsidies (e.g. for building isolation) or regulatory standards and spatial planning. Other examples are the management of water supplies, the restoration of ecosystems and research to better understand new weather patterns, in particular to create and inform early warning systems. Adaptation also means societies need to prepare for life in a different climate and make changes to their skill sets.

Allocating resources to climate change adaptation means changing the composition of demand and focusing more on investment to strengthen or substitute production factors at risk. It may have aggregate effects on consumer prices (e.g. additional investment boosting aggregate demand) and entail changes in relative prices (see Box II.2). Reducing future vulnerability to climate change will also reduce future price volatility with respect to a counterfactual of no adjustment.

II.3.2. Mitigating climate change

Policies that limit GHG emissions and mitigate future climate change ([58]) also affect current economic activity and prices (see Boxes II.1 and II.3). A wide range of policy tools exist, such as the pricing of emissions, environmental taxation, regulation and subsidies, which can affect output and prices through various channels. For a given state of technology, curbing emissions puts a burden on current economic activity, as explained in Nordhaus's influential model (1991) ([59]). Climate action thus involves clear intertemporal trade-offs. The 2015 Paris Agreement provides the legal framework for curbing GHG emissions and limiting global warming to well below 2 °C– and preferably to 1.5 °C –above pre-industrial levels. In the EU, this goal is pursued through the European Green Deal and the European Climate Law ([60]), which makes climate neutrality in the EU binding by 2050. It includes the 'Fit for 55' legislation

([56]) For the EU climate adaptation strategy see, European Commission Communication (COM(2021) 82 final), [Forging a climate-resilient Europe - the new EU Strategy on Adaptation to Climate Change].

([57]) European Commission Communication (COM(2024) 91 final), [Managing climate risks - protecting people and prosperity].

([58]) A beneficial byproduct of climate policy is air quality improvement and implications for public health.

([59]) Nordhaus analyses the costs and benefits of the emissions effect and policies in terms of two fundamental functions: a *greenhouse damage function*, which describes the costs to society of the changing climate (including the types of costs described in the previous subsection) and an *abatement cost function*, which describes the costs to the economy of preventing or slowing the greenhouse effect. (Nordhaus, 1991, To Slow or Not to Slow: The Economics of The Greenhouse Effect, The Economic Journal, July, 1991, Vol. 101, No. 407 (July, 1991)).

([60]) Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 ('European Climate Law').

package, through which the EU aims to reduce its net emissions by at least 55% relative to the 1990 level, by 2030 ([61]). As discussed in this sub-section, climate change mitigation will directly affect prices and inflation patterns.

The links between CO2 emissions and the macroeconomy can be better understood through the 'Kaya identity', which decomposes CO2 emissions generated from energy use as follows (see Batten (2016) ([62])):

$$CO_2 = Population \times \frac{GDP}{Population} \times \frac{Energy}{GDP} \times \frac{CO_2}{Energy}$$

It expresses CO2 emissions as a product of four underlying drivers, namely population, (potential) GDP per capita, energy intensity of GDP and carbon intensity of energy use. It highlights a series of trade-offs, notably between output and emissions. Accordingly, for a given output, lowering emissions would require either lower energy intensity (i.e. higher energy efficiency) or less carbon-intensive energy production (e.g. by switching to renewable sources of energy). The challenge is to continue decoupling economic activity and growth from carbon and emissions, which requires switches in energy production methods and supply lines.

Price signals, and carbon pricing in particular, play an important role in the transition to lower GHG emissions. Changing price signals to better capture the social costs of carbon-intensive goods will reduce demand for such goods and produce more efficient outcomes overall. Internalising the externality through the carbon price – whether implemented as a carbon tax or a market-based cap-and-trade system, as is the case for the EU ([63]) – is in line with the polluter pays principle and provides an incentive to reduce emissions. Introducing a carbon price acknowledges that carbon emissions (i.e. the right to pollute) are similar to a resource used in the production process. Their cost – just like that of any other input –needs to be covered, instead of being made available available for free (Box II.3) ([64]). For a fixed emissions cap, the carbon price (or the carbon tax payment for a given carbon tax rate) will largely depend on the marginal abatement cost curve, i.e. the cost of reducing emissions. The additional cost (abatement or permits) borne by firms in sectors covered by the ETS causes the production cost of carbon-intensive goods to rise steadily. The effect on consumer prices will evolve over time, depending both on the emission reduction path and how quickly carbon abatement technologies develop. However, two further effects may be relevant. Firstly, introducing carbon prices or taxes will have a negative effect on income. This will decrease aggregate demand and may have a disinflationary effect. Secondly, reducing dependence on imported fossil fuels, will eventually reduce their role in causing inflation volatility. Indeed, prices of fossil energy sources, such as crude oil and natural gas, have been the main driver of inflation volatility in the recent past and have been the main factor behind the inflation surge in 2022.

Carbon pricing and other incentives to substitute carbon-rich commodities should reshuffle demand. All else being equal, they will reduce demand for carbon-intensive goods and drive-up demand, and prices,

([61]) Up from a previous gross target of 40%. The EU further aims to become climate-neutral by 2050, i.e. achieve 'net zero' emissions. Beyond this, 18 of the G20 countries, as well as many cities and firms have also made that pledge (https://zerotracker.net/analysis/g20-net-zero-stocktake).

([62]) Batten, Sowerbutts, and Tanaka, 2016, Let's Talk About the Weather: The Impact of Climate Change on Central Banks. Bank of England Working Paper No. 603.

([63]) The EU ETS is a 'cap and trade' system in place since 2005. The cap limits the total amount of GHGs that firms covered by the system are allowed to emit ('allowances'). The cap is reduced every year, ensuring that emissions decrease over time. Firms receive some allowances for free and, within the cap, can buy others on the EU carbon market. This enables governments to generate revenues, which can in turn be allocated to emissions-reducing investments (e.g., low-carbon technologies). Allowances can be traded among firms on the secondary market, which establishes a market value for them.

([64]) The carbon price is subject to repricing risk, because its social cost, which also depends on the discount rate applied, cannot be established with certainty (Tol, 2018).

for non-carbon intensive goods and commodities, or abatement technology ([65]). Such price increases during the transition process are sometimes referred to as ‘greenflation’. Overall, the introduction of carbon pricing hence changes relative prices, while having a negative income effect. However, the latter is likely be counterbalanced by the large public and private investments that are needed to follow the ‘net-zero emissions pathway’, which will increase demand ([66]). The impact of carbon pricing on consumer prices (‘carbon pass-through’) hence depends on the level of emission caps and on the share of goods produced by sectors covered in the consumer basket. The introduction of carbon pricing will have a one-off impact on prices and ultimately on inflation ([67]), which may evolve over time as the carbon price changes and demand adjusts. The effect on consumer prices may be relatively direct (in the case of air transport) or less direct (as with chemicals and maritime transport).

Recent empirical evidence on the carbon pass-through indicates mild inflationary effects so far. Känzig (2023) ([68]) shows that while a restrictive carbon policy shock causes a persistent fall in overall GHG emissions – consistent with the stated objective – it also leads to a temporary increase in energy prices and a decline in economic activity. Känzig also points out that this does not affect all parts of society in the same way. Thus, poorer households are hit harder as they spend more of their income on energy and experience larger falls in income. Moessner (2022) ([69]) finds that a USD 10 increase in the price of ETS per tonne of CO2 equivalents raises energy CPI inflation by 0.8 percentage points (pps) after one year, and headline inflation by 0.08 pps, but has no significant effects on food and core CPI inflation. Meanwhile, an equivalent increase in carbon taxes only has a marginal effect on food inflation. Konradt and Weder di Mauro (2023) ([70]) find that carbon taxes in Europe and Canada have caused relative price changes, increasing the cost of energy. However, they find no evidence for significant increases in headline inflation or spillovers to core inflation, suggesting that central banks can accommodate potential inflationary pressure associated with carbon pricing. Likewise, Konradt et al. (2024) ([71]) estimate that the EU ETS and national carbon taxation in euro area countries have raised the price of energy but have had limited effects on overall consumer prices. Santabárbara and Suárez-Varela (2022) find strong evidence that cap-and-trade schemes (such as the EU ETS) make headline inflation more volatile. ([72])

The limited carbon pass-through found in some recent studies, may not necessarily be very insightful for future. Rather, it could indicate relatively low carbon prices during the periods assessed in the studies, or generous initial ETS allowances, combined with low marginal abatement cost. This would suggest that it has so far been relatively easy to switch technologies, with limited impacts on costs overall. However, the carbon price would need to rise as a result of (i) the need to step up climate policies due to the increasingly strong impact that climate change will put on societies and economies if not mitigated, and (ii) the upward sloping marginal abatement cost curve, which will progressively make it costlier to substitute technologies. Konradt et al. (2024) estimate that for the EU to reach its ‘Fit for 55’

([65]) For instance, reducing emissions by combining higher energy efficiency and energy production that is less carbon-intensive (cf. Kaya identity) implies a switch to a mineral-rich model, as ‘clean’ energies such as solar photovoltaic plants, wind farms and electric vehicles generally require more minerals than their fossil fuel-based counterparts (International Energy Agency, 2021, The Role of Critical Minerals in Clean Energy Transitions). Mineral supply is fixed in the short-term, while longer-term supply expansion requires prolonged and significant investments, which may be challenging depending on their geographic allocation.

([66]) The International Energy Agency estimates that that total annual capital investment in energy would need to rise from 2.5% of global GDP to about 4.5% in 2030 before falling back to 2.5% by 2050 (International Energy Agency, 2021, Net Zero by 2050: A Roadmap for the Global Energy Sector). Note that carbon revenues can be used to finance these investments.

([67]) An increase in carbon price would thus be similar to a cost-push shock.

([68]) Känzig, 2023, The Unequal Economic Consequences of Carbon Pricing. No. w31221. National Bureau of Economic Research.

([69]) Moessner, 2022, Effects of Carbon Pricing on Inflation, CESifo Working Paper No. 9563.

([70]) Konradt and Weder di Mauro, 2023, Carbon Taxation and Greenflation: Evidence from Europe and Canada, Journal of the European Economic Association, Volume 21, Issue 6, December 2023.

([71]) Konradt, McGregor and Toscani, Carbon Prices and Inflation in the Euro Area, IMF Working Paper WP/24/31.

([72]) Santabárbara and Suárez-Varela, 2022, Carbon Pricing and Inflation Volatility. Banco de España Working Paper No. 2231.

commitments, carbon prices would need to rise to EUR 150 per tonne of CO2 by 2030, which could add 0.2-0.4 pps to annual euro area inflation per year, depending on the pass-through scenario. ([73]) Upward carbon price pressures should ease over time as firms adopt new technologies and as the economy decarbonises.

II.4. IMPLICATIONS AND CONJECTURES ON FUTURE INFLATION CHARACTERISTICS

Climate change, caused by an unsustainable carbon-intensive production system, presents a major ongoing and open-ended global challenge. Europe, the continent that is warming most rapidly, is no exception. Regardless of whether it is 'ignored' or actively tackled through adaptation and mitigation actions, climate change will impose and require major structural changes in the global economy. Its impacts are however expected to vary in different places and at different times since regions' contribution to GHG emissions and their exposure to climate change vary. Climate change is a process that has been building up over decades and will continue in the future. It is not a sudden shock or single event like the COVID 19 pandemic. As illustrated in this article, climate change will continue to have a significant effect on prices, which can be viewed both as adjustment variables in response to climate shocks, and as instruments steering the transition to a low-carbon economy and the adaptation to higher temperatures. Thus, climate change can be expected to significantly affect inflation dynamics.

This chapter has explored and illustrated different transmission channels through which climate change can affect prices and inflation. However, its scope does not extend to quantifying the effects of climate change and climate action on inflation, although this clearly warrants further research. Nonetheless, several reasonable qualitative conjectures regarding the nature of future (euro area) inflation emerge from the analysis presented here:

- **Inflation will likely become more volatile** as extreme weather events around the globe become more fraquent and intense or as seasonal price patterns change (Graph II.6). There will be more uncertainty around inflation dynamics, as the type, timing, frequency, and location of extreme weather events cannot be predicted. As negative supply shocks, they will drive up the prices of the affected goods and hence temporarily raise headline inflation. In economies where prices tend not to fall (downward price rigidities), higher inflation volatility could thus lead to upward inflation pressures. However, as many climate shocks result in lower wealth or confidence, they may also have negative demand effects that partially offsett inflation.

- **The transition to a low-carbon economy will likely put upward pressures on inflation and will lead to relative price realignments**. Climate policies that are rigorous enough to achieve the stated objectives are expected to add price pressures in the transition phase to a low-carbon economy. Policies to bring about the phasing out of fossil fuels and of carbon-intensive technologies are likely to result in higher production costs, at least in the short-run. These policies are hence likely to primarily affect consumer prices of energy and of goods falling under the broadening ETS coverage. These effects will last at least for the duration of the supply-side transition to a low-carbon and more resource-efficient economy. Their magnitude is subject to uncertainty, as it will hinge on the resolve both domestically and abroad to implement climate

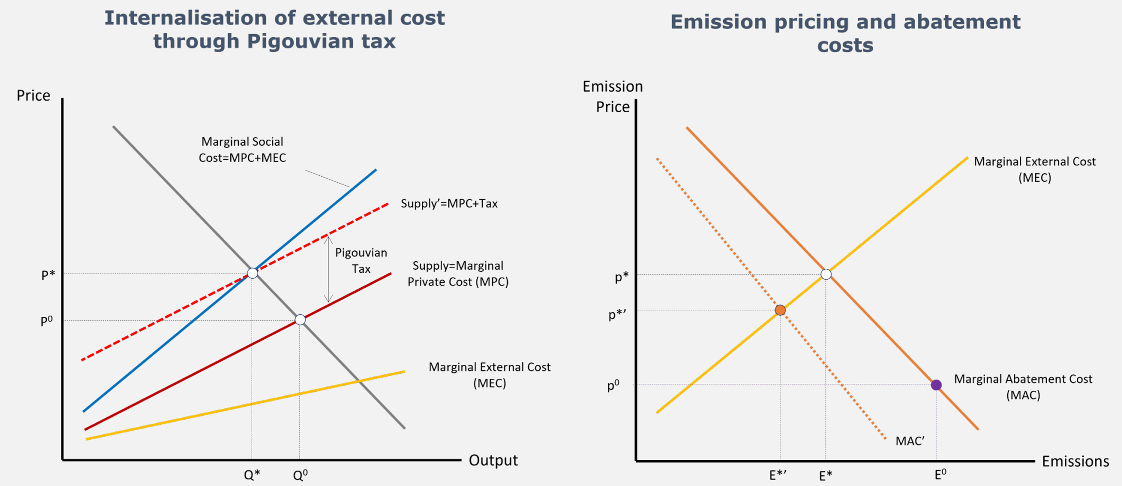
([73]) This is marginal when compared to the surge of euro area inflation to 8.4% in 2022, when the energy component contributed 3.8 percentage points after increasing by 37%.

Box II.3: **Pricing mechanism to steer the mitigation of climate change**

To limit climate change of new GHG emissions must be reduced. Pricing mechanisms play a key role in climate change mitigation policies, as illustrated in Box II.1.

Negative production externalities are the underlying economic problem that policy needs to address. If producers ignore the external costs of emissions, there will be more production than is socially optimal. This is illustrated in the figure on the left-hand side of the graph below, which shows that a producer focusing on their private cost only, will produce output Q^0 and charge P^0 per unit of the good. If the producer were also to consider the external cost and focused on social cost instead (the sum of private and external cost), they would scale down production to Q* and raise the price to P*. The negative effect on consumer welfare resulting from a higher price and lower output, would however be offset by the positive effect of reduced emissions. One way to eliminate the negative externality and achieve a socially efficient outcome would be to charge the producer a corrective ('Pigouvian') tax equivalent to the marginal external cost, in line with the polluter pays principle. The socially efficient outcome would therefore result in a higher (relative) price for a good with a production process involving emissions. Addressing the externality through a tax or by selling emission permits would generate fiscal revenues, which could in turn be used to tackle the consequences of climate change or to help mitigate it.

Graph 1: **Climate change mitigation: putting a price on negative externalities**



Note: The figure on the left shows how compensatory taxation addresses a negative production externality to achieve a social optimum. The figure on the right shows how the price of emissions depends on the available abatement technology.

Firms must now either pay for their emission (through a tax or by purchasing a permit) or invest in cleaner technologies to abate their emissions. This is illustrated in the figure on the right-hand side of the graph. For a given abatement cost function, a market outcome would be a level of emissions of E* units, for which a price p* is charged. If a government set an emission price at a level p^0 instead, where $p^0 < p^*$, there would be excess emissions (E^0- E*), for which external costs would exceed abatement cost. The figure illustrates how a positive technology shock would lead to a fall in in abatement costs, i.e. making it less costly to lower emissions. This is represented by an inward shift of the marginal abatement cost curve, which results in a new market equilibrium with both lower emissions (E*') and a lower emissions price (p*').

Compared to a situation in which no policy is implemented, pricing GHG emissions (or limiting them under a market-based cap-and-trade system) lead to higher prices for consumers or an additional production cost which firms may pass on to consumers. Emissions pricing also illustrate the key role of price signals in reducing the negative externality. Price signals ultimately create incentives to decarbonise or to innovate and develop technologies that abate emissions.

policies. Thus, implementation delays and half-hearted climate policies may themselves become a source of inflation volatility.

- **How inflation volatility develops over time will depend on adaptation and mitigation efforts**. Expected inflation volatility over time depends on near-term adaptation and mitigation, which are expected to increase inflation during the transition. While adaptation and mitigation efforts could also result in some near-term inflation volatility, their impact on individual prices could be relatively predictable if they are implemented in an orderly fashion. A benefit of these efforts is that inflation volatility caused by extreme weather events should be lower in a more distant future. Likewise, a successful energy transition will change the drivers of current inflation volatility. Prices of imported fossil fuels have been the main source of inflation volatility in recent years and the main driver of the 2022 inflation surge. Rolling back the dependency on imported fossil fuels should thus also help in reducing their contribution to inflation volatility.

- **Climate change will affect a wide array of prices.** The agricultural sector's dependence on the weather and natural resources means that it is particularly exposed to climate change, and this directly affects food price levels and volatility. However, climate change and disruptive weather events affect the functioning of many other sectors or individual production facilities. This may, for example, be due to vulnerabilities resulting from their reliance on a certain natural resource (e.g. water), or their exposure to weather shocks, which may also result in transport disruptions. In addition, many sectors will be subject to mitigation measures, and thus higher production costs, which they may pass on to consumers.

Changing inflation characteristics will affect inflation analysis and economic policy. Some tentative implications emerge from this analysis to illustrate how climate change could interfere with non-climate issues and policies.

- **Inflation will likely become harder to interpret.** Inflation volatility and shifts in relative prices complicate the interpretation and perception of inflation and could make it harder to separate price signals from noise. The shocks associated with climate change, adaptation and mitigation have different characteristics (supply or demand shock; transitory or permanent; etc.) and transmit to prices through different channels. Disentangling them will be complex, especially if they occur simultaneously. The situation in the euro area is more complex because different regions are affected differently by climate change, with southern Europe and the coastal regions expected to be particularly affected. Climate change could therefore become an additional source of inflation dispersion.

- **Inflation will likely become harder to forecast**. Price volatility and the multiplication and intensification of potential shocks will make it more complicated to quantify their aggregate effects and integrate them into a baseline forecast scenario. All else being equal, forecasts will become more uncertain and will therefore offer households and firms and policymakers less reliable guidance for decision-making. Correspondingly, *ex post* forecast errors are likely to increase, which may affect the credibility of and trust in forecasts and the institutions making them.

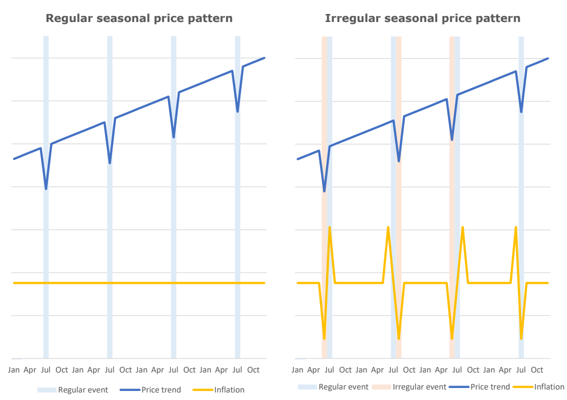
- **How inflation expectations are formed may change.** High price volatility, in particular for key prices, such as those of food and energy, could weaken the anchoring of households' inflation expectations to inflation targets ([74]). One reason for this is that people often attach a higher weight to positive price changes than to negative ones. This could bias inflation perceptions and expectations upwards. Inflation volatility could thus create conditions that are conducive to prolong

([74]) See for example: Cavallo, Cruces and Perez-Truglia, 2017, Inflation Expectations, Learning, and Supermarket Prices: Evidence from Survey Experiments, American Economic Journal: Macroeconomics; D'Acunto, Malmendier, Ospina, and Weber, 2019, Exposure to Daily Price Changes and Inflation Expectations, NBER Working Paper No. 26237.

temporary shocks through second-round effects. A greater irregularity in seasonal price patterns, as illustrated in Graph II.6, could thus potentially accentuate perception biases. Market-based indicators of inflation expectations could become noisier on account of higher risk premimums. And while it would be justified for a central bank to ignore or 'look through' adverse temporary supply shocks, the impact on inflation expectations will depend on whether economic agents share its assessment and trust its explanations. ([75]) However, communication regarding inflation is likely to become more challenging the longer the supply shock lasts and the more entangled the shocks become ([76]).

- **Greater uncertainty may complicate macroeconomic policymaking.** Climate change will affect output and prices. This will make it more challenging to estimate economic potential and growth and, by extension, to determine the cyclical position of the economy, which is a prerequisite for many macroeconomic policies. A growing number of studies discuss the implications of different types of climate shocks for monetary policy (e.g., Batten et al (2020); ([77]) McKibbin et al. (2020); Rudebusch (2019); ECB (2021); Bank of England (2022); Schnabel (2022); Apel (2022)) ([78]). As discussed above, when there are downward nominal rigidities, inflation volatility can result in an inflationary bias. However, if inflation volatility is the outcome of relative wage adjustments across sectors as the economy transitions to a low carbon economy, higher inflation could indeed be the byproduct of a smooth transition. (Note that downward wage rigidities are one major reason for pursuing a positive inflation target). A dilemma that could arise for a central bank in such a context of structural adjustment, would be whether to tolerate possible deviations from its inflation target to help

Graph II.6: **Inflation impact of irregular seasonal price patterns**



Note: the graph illustrates the impact on inflation when a seasonal price pattern becomes irregular. If prices have a regular seasonal pattern (left panel), e.g. a drop each July following a harvest, year-on-year inflation is not impacted. If the timing of price drops now alternates between June, July and August (right panel), say because of climate change-induced irregularities in harvest patterns, this will create inflation volatility, even if the price trend remains unaffected.

Source: Own illustration.

([75]) An adverse impact of climate change on confidence may also contribute to higher inflation expectations by households, which typically adopt a "supply side view" of macroeconomic shocks.

([76]) Higher inflation volatility may also erode the trust in inflation statistics. Anecdotally, this can be illustrated by the recent prominence of the neologism "shrinkflation", loosely referring to reduced product sizes for an unchanged price. In the context of this article, it is worth noting that the reduction in the size of processed food items (e.g. chocolate bars) may reflect shortages of food commodities (e.g. cocoa) inter alia due to climate change (e.g. Unctad, 2024, Chocolate price hikes: A bittersweet reason to care about climate change).

([77]) Batten et al (2020) review several central bank decisions in responses to natural disasters. The US Fed hiked interest rates after Hurricane Katrina in 2005, which it saw as a temporary supply shock. Meanwhile, the Bank of Japan eased its monetary policy following Great East Japan Earthquake, viewing it primarily as a negative demand shock. The Bank of Canada (Lane, 2017) considered the introduction of carbon pricing as a one-off structural change and looked through it in making monetary policy.

([78]) McKibbin, Morris, Wilcoxen, and Panton. 2020, Climate Change and Monetary Policy: Issues for Policy Design and Modelling, Oxford Review of Economic Policy 36 (3): 579–603; ECB, 2021, Climate change and monetary policy in the euro area, ECB Occasional Paper No 271; Rudebusch, 2019, Climate Change and the Federal Reserve, FRBSF Economic Letter; Bank of England, 2022, Climate change: possible macroeconomic implications, Quarterly Bulletin 2022 Q4; Schnabel, 2022, A New Age of Energy Inflation: Climateflation, Fossilflation and Greenflation; Speech 17 March 2022; Apel, 2022, How does the climate transition affect inflation? Economic Commentary, No. 13, Sveriges Riksbank.

facilitate the transition, or to risk an overly restrictive monetary stance to hit its target [79].

Climate change is causing momentous structural transformations for life on our planet for which there is no precedent. Just as many aspects of it remain subject to great uncertainty, there is also uncertainty on the global resolve to tackle it. Thes uncertainties are due partly to different intertemporal trade-offs, but also to political economy constraints within and across countries and to misaligned incentives. At the same time, the EU and world economies are going through several other structural transformations, such as ageing, geopolitical tensions, changes to globalisation and digitalisation. These transformations will on the one hand interact with climate change and on the other hand affect inflation through their own channels. Inflation disruptions of some form seem unavoidable.

(79) Guerrieri, Lorenzoni, Straub and Werning, 2021, Monetary Policy in Times of Structural Reallocation (September 15, 2021). University of Chicago, Becker Friedman Institute for Economics Working Paper No. 2021-111.

III. SECTORAL WAGE SHOCK AND INFLATION IN THE EURO AREA

By Aron Kiss, Giulia Maravalli, Matteo Salto and Kristine Van Herck

Abstract: *This chapter analyses how shocks to nominal wages affect consumer prices when taking into account the sectoral structure of the economy. Sectoral interlinkages of the economy are accounted for by using an input-output model. The chapter shows that, on top of their direct impact on production prices, wage increases may also have a sizeable second round indirect impact on prices via their effect on the cost of intermediate inputs. Moreover, a wage shock in a specific sector can have a very different impact on inflation depending on not only the sector's labour intensity but also its position in the production chain; sectors that provide more inputs to the rest of the economy have a larger impact, other things being equal. Measures of stress in the labour market, like the vacancy rate, currently seem correlated with wage growth and are relatively concentrated in sectors somewhat upstream in the production chain. This means that, if wages grow faster in sectors with higher vacancy rates, this may result in relatively stronger inflationary dynamics than if wages increased by the same rate in all sectors. However, the magnitude of the effects suggests that a gradual recovery of real wages is consistent with a continuation of gradual disinflation in the euro area as productivity increases and unit profits decline ([80]).*

III.1. INTRODUCTION

The inflation surge that has hit the euro area economy as from 2021 has been exceptionally significant. A succession of supply shocks played the main role in that surge, related first to goods shortages caused by disruptions in supply chains, and then followed by energy and food price shocks, partly due to Russia's unjustified military aggression against Ukraine. A role was also played by demand factors, due to pent-up demand for goods and especially services generated by the excess saving during pandemic lockdowns.

The effects of those shocks are now fading. As shown in Graph III.1, having peaked at 10.6% in October 2022, euro area inflation has since declined significantly to reach 2.4% in April 2024. Rapid fall in retail energy prices throughout 2023 was the main driver of the inflation decline, but underlying inflationary pressures started easing too in the second half of 2023, amidst the weak growth momentum.

In the context of economic weakness, the labour market showed signs of continued strength with unemployment at 6.5% in March 2024, almost an historic low for the euro area. Despite the decrease in inflation observed in 2023, and the gradual nominal wage increase observed as from 2021, real wages fell significantly during the surge in inflation and the early stages of the disinflation process. The cumulated fall in real wages between Q2-2022 (the peak) to Q2-2023 (the trough) was about 4.5% in the euro area (Graph III.2 shows the yearly growth rates of these variables) ([81]).

The third quarter of 2023, when growth of real compensation per employee turned positive on a quarter-on-quarter basis, likely represents a turning point in real wage developments, also in view of the decrease in inflation. Nominal wages now outpace inflation, even if they seem to have reached a plateau

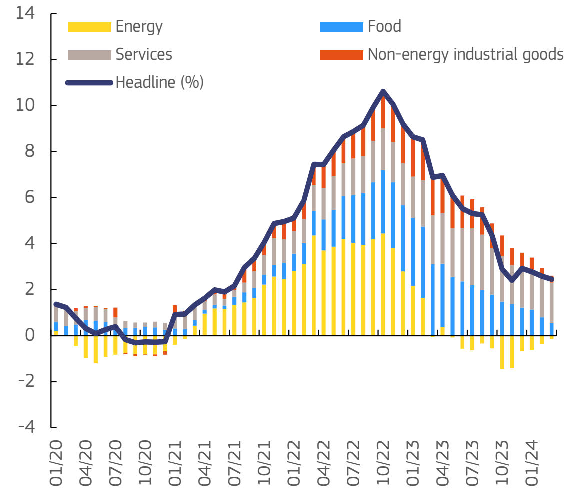
([80]) We thank E. Ruscher and L. Coutinho for valuable comments and L. Biedma for invaluable help with the data.

([81]) This is when the nominal wage is adjusted with consumer prices, the measure of real wage growth relevant for workers. Note however, that the fall in real wages has been smaller when real wage growth is adjusted with the GDP deflator, a measure that more closely approximates the calculus of employers when they define their demand for labour. Nominal wages are measured as nominal compensation per employee. Note that data for 2020 and 2021 may be distorted by the presence of the schemes supporting employment during the COVID-19 crisis.

in the middle of 2023: nominal compensation per employee expanded by 5.8% in 2023 in the EU, with a gradual deceleration in the second half of the year.

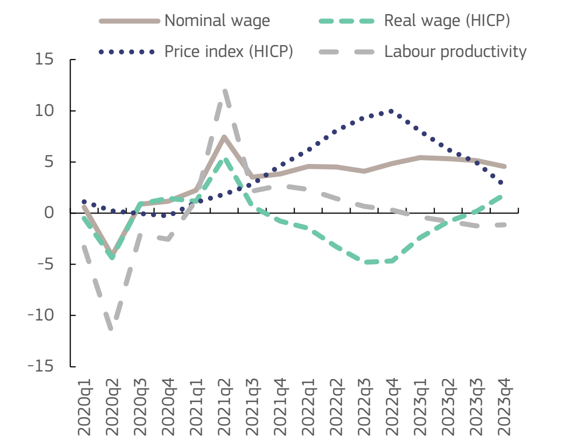
According to the Commission's Spring 2024 Forecast ([82]), nominal wage growth is projected to moderate gradually in 2024 and 2025, but to exceed inflation in both years, finally allowing workers to recoup the losses in purchasing power since 2021. This is still compatible with inflation coming back to target as unit profit growth is also expected to ease and labour productivity is set to recover over the forecast horizon. In real term, wages are set to fully recover their 2021 levels by 2025 as slowing, but still high nominal wage growth is accompanied by falling inflation.

Graph III.1: **Euro area HICP and contributions after 2020**



(1) The graph shows year-on-year HICP growth rates and the contributions of the main subcomponents.
Source: Eurostat and own calculations.

Graph III.2: **Euro area growth in nominal and real wages after 2020**



(1) Nominal wages are measured as nominal compensation per employee. Real wages as the difference between nominal wages and HICP.
Source: Eurostat and our calculations.

Despite those positive developments, some observers have stressed the importance of monitoring wage developments in the context of the disinflation process, also in relation to high nominal wage growth and the stickiness of services inflation, which has been stable at 4% in recent months ([83]). The relation between wage growth and inflation is indeed at the core of policy-making and, consequently, of analysis.

The literature on the relation between wage increases and inflation in the euro area is vast. The "cost-push" view whereby increases in labour costs are a source of consumers price inflation plays a significant role in policy making. A strong link between labour cost and price inflation has been found empirically in the case of the euro area ([84]). For instance, Bobeica et al. use data for Germany, France,

([82]) European Commission (2024), European Economic Forecast available at [Spring 2024 Economic Forecast: A gradual expansion amid high geopolitical risks - European Commission (europa.eu).](#)

([83]) Recently, despite the observed deceleration in inflation, the ECB has stressed that "wage growth is expected to become an increasingly important driver of inflation dynamics in the coming quarters, even if the declining contribution of profits to inflation suggests that labour cost increases are not being fully passed on to consumers".

([84]) This explanation has been put in doubt in the US. A number of studies favour the neoclassical view that price inflation causes wage inflation rather than the opposite New-Keynesian view, and that the causality can differ across sectors. For example, Knotek et al. (2014) do not find that labour cost increases precede or follow price increases and Peneva et al. (2017), find little evidence that independent movements in labour costs have had a material effect on price inflation in recent years. Knotek, E. S. and Zaman, S. (2014), "On the Relationships between Wages, Prices, and Economic Activity," Economic Commentary, (Aug); Peneva E. V. and Rudd, J. B. (2017), "The Passthrough of Labor Costs to Price Inflation," Journal of Money, Credit and Banking, 49(8):1777–1802.

Italy, and Spain both for the economy as a whole and for services, manufacturing, and construction to show that over 1985-Q1-2018-Q1 there was a strong link between labour cost and price inflation ([85]). Such a link depends on the state of the economy and on the shocks hitting the economy; the pass-through of labour costs on to price inflation is more likely under demand shocks than under supply shocks ([86]). However, the existing literature also tends to conclude that, notwithstanding the existence of labour cost pass-through, risks of a wage-price spiral in the euro area are limited ([87]).

More recently Arce et al. replicate the semi-structural model developed for the US by Bernanke and Blanchard ([88]) to break down the effect of the main drivers of inflation in the euro area. Their findings point to the relevance of supply-side shocks, 'with a more limited role for demand shocks as captured by labour market tightness, notwithstanding the supply-demand imbalances due to pent-up demand and supply chain disruptions.' They find that real wage catch-up and bargaining resulted in higher nominal wage growth, but that labour market overheating, as measured by the job vacancies to unemployment ratio, only started to impact wage growth and price inflation in the euro area towards the end of 2023 ([89]). The pre-COVID elasticity that they find in their wage equation with respect to their measure of labour market stress is 0.3, while the elasticity of inflation to nominal wage growth is almost 0.5, both lower than inflation expectations and past inflation respectively.

Notwithstanding the substantial empirical literature on the link between inflation and wages, little is known of the impact of the sectoral structure on the propagation of wage shocks to consumption prices. In particular do wage shocks in different sectors have sizeably different implications for consumer prices? This is a relevant gap in the literature because to understanding how a wage shock propagates to final prices, it is necessary to take into account the sectoral dimension of the wage shock and the interaction across different sectors. It also makes it possible to analyse the effect of the sectoral dimension of a wage shock itself. This analysis can only be conducted using an input-output model, and this is what the present chapter does. While this can be considered a relatively standard exercise ([90]), we are not aware of any recent application of input-output models to analyse this question for the euro area.

The present chapter analyses the impact on inflation of a 5% increase in nominal wages under the assumption of a simple input-output model. This is a purely hypothetical shock and results would not change qualitatively for a shock of a different magnitude. To better understand the link between shock propagation and the sectoral structure of the economy, three illustrative simulations are analysed. The simulations are based on different assumptions as to the sectoral allocation of the overall 5% wage shock.

([85]) Bobeica E., M. Ciccarelli, I. Vansteenkiste (2019) "The link between labour cost and price inflation in the euro area", ECB WP 2235. For a model-based analysis, see also Gumiel, J. E. and Hahn, E. (2018), "The Role of Wages for the Pick-Up in Inflation", Economic Bulletin Issue 5, ECB.

([86]) See also the speech by Christine Lagarde, President of the ECB, at the plenary session of the European Parliament, Strasbourg, 26 February 2024, European Parliament plenary debate on the ECB Annual Report (europa.eu) and Blanchard, O. (2022), "Why I worry about inflation, interest rates, and unemployment," Realtime Economic Issues Watch, 14 March

([87]) For example, Alvarez et al. (2022) show that only a small minority of episodes of large acceleration of nominal wages were followed by further sustained acceleration in (wages and) prices. See Alvarez J., J. Bluedorn, N. Hansen, Y. Huang, E. Pugacheva, and A. Sollaci (2022), "Wage-price spirals: What is the historical evidence?", IMF WP 22/221, and Baba, C. and J. Lee (2022), "Second-round effects of oil price shocks—Implications for Europe's inflation outlook," IMF WP 22/173.

([88]) See previous footnote.

([89]) "However, caution is needed when interpreting the consequences of high labour market tightness on wages [in recent quarters], as the model may fail to recognise that real wages might not have been able to catch up with past inflation if the labour market had not tightened." Arce O., M. Ciccarelli, A. Kornprobst, and C. Montes-Galdón (2024), "What caused the euro area post-pandemic inflation? An application of Bernanke and Blanchard (2023)", ECB Occasional Paper Series 343. The paper to which they refer is Bernanke, B. S. and Blanchard, O. J. (2023), "What Caused the US Pandemic-Era Inflation?", NBER WP 31417.

([90]) See Miller R. E. and P. D. Blair (2009), "Input-Output Analysis. Foundations and Extensions", Cambridge University Press, second edition, Chapter 12 for a very clear exposition of the problems and of the model used here.

The chapter shows that the characteristics of the sectors where the shock takes place play a role in the transmission of wage shocks to inflation. First, wage shocks in larger sectors have a bigger impact than those in smaller sectors. Second, wage shocks taking place in sectors that are more labour-intensive have a bigger impact on inflation. Finally shocks in more upstream sectors influence the costs of more sectors, and therefore have a bigger impact on inflation.

The rest of the chapter is organised as follows. Section III.2 discusses the hypothetical wages shock used in the three simulations, also in relation to the evidence on labour market developments in the different sectors, stressing the existing tensions and their potential role in the increase in nominal wages. Section III.3 compares the different effects on inflation of the three possible shocks considered. Section III.4 discusses the result of the simulation and Section III.5 provides conclusions.

III.2. THE METHODOLOGY USED FOR THE SIMULATIONS

As explained in more details in Box III.1, the simulations are based on a standard set of assumptions used in the application of input-output models ([91]). An input-output model for the euro area separates its economic activity into producing sectors. Each producing sector demands intermediate inputs from other sectors, and primary inputs from the rest of the world and from workers and capital owners, in order to serve the other sectors and the final demand. Traditionally, the input-output model is interpreted as demand model. Firms have a Leontief production function with fixed input and labour coefficients. The Leontief coefficients are computed as the ratio of the value of each input used to produce the output of a given sector to the total output of that sector. The model then makes it possible to compute the inputs across the economy's different sectors that are necessary to satisfy a given final demand.

However, this model can also be used to compute the impact of cost shocks on downstream sectors and final demand ([92]). In this case, the shock to the input cost is passed forward onto the rest of the economy, with downstream firms reflecting the shock.

In the present analysis, the cost shock is represented by an exogenous percentage increase in wages ([93]). The increase is passed on by firms to their prices. The increase in those prices becomes the increase in intermediate costs for downstream sectors. The downstream sectors then pass on the increase in intermediate costs generated by wage increases in their upstream domestic sectors (and in their own wages) on their output prices. This generates a new vector of output sectoral prices ([94]).

It should be noted that this method assumes, implicitly, that i) firms were optimally choosing their prices at the moment they were hit by the shock, given the increase in costs of the previous years; and ii) firms, having a Leontief production function pass on all increases in costs (prices and wages) to their output prices. The increases in prices that are found in the simulations can therefore be interpreted as an upper bound to the price increases that should result from the shock. This is because should the production

([91]) Among very many presentations of the input-output models, for a complete and simple treatment see Miller R. E. and P. D. Blair op. cit.

([92]) For a recent policy application to the effects of the increase of oil see European Commission (2023), "Inflation Differentials in Europe and Implications for Competitiveness. Thematic Note to support In-Depth Reviews", Institutional Paper 198/2023.

([93]) In practice, labour costs are increased by the chosen amount, assuming implicitly that social contributions remain proportional to wages.

([94]) Strictly speaking, this is done using the Ghosh model. This is the input-output model where one keeps fixed the ratios of matrix representing the transactions of intermediate goods divided by the output per row, as opposed to the Leontief model in which one keeps fixed the ratios by column. The Ghosh model per se does not have a meaningful economic interpretation, while the Leontief model can be interpreted in terms of fixed production coefficients. However, the two give the same results under the assumption that the percentage changes following the shock are interpreted as price changes, which is our case. See Miller R. E. and P. D. Blair op. cit.

function be different, firms would react by (in part) substituting more costly inputs with less costly ones leading to a smaller increase in final prices ([95]).

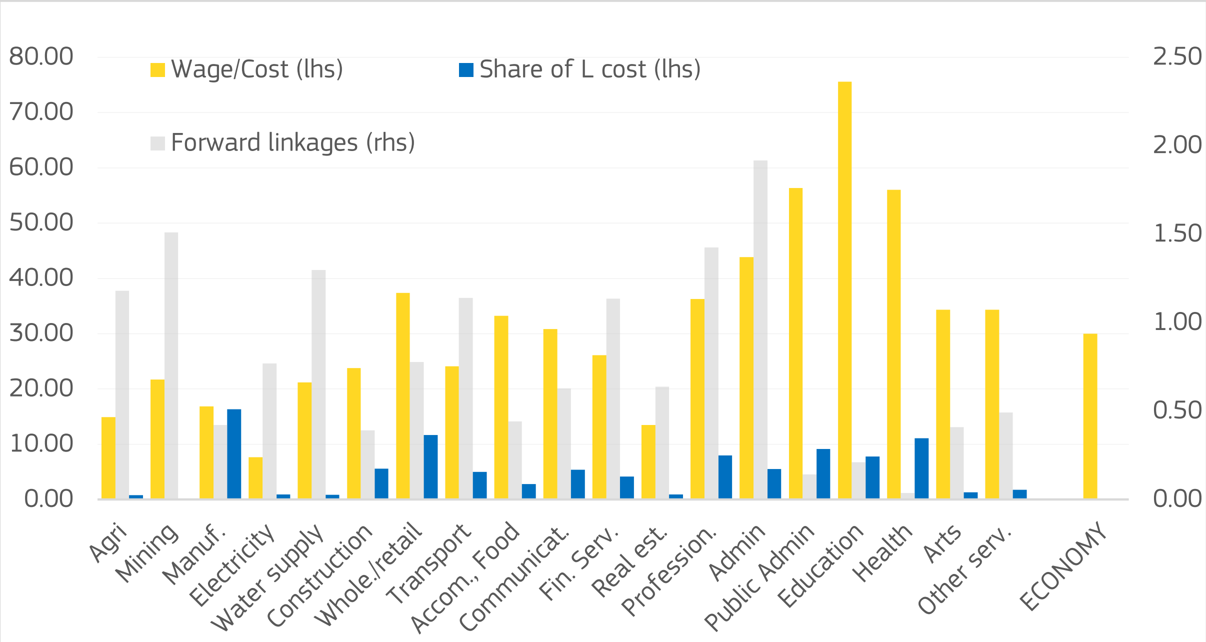
Finally, a corresponding new vector of final consumption prices is computed, which is consistent with the new output prices ([96]). Sectoral price increases are then aggregated using the sectoral shares of the consumption vector, with the aggregate increase representing the effect of the wage shock on consumer prices.

Thus, the reaction to a wage shock can loosely be conceptualised in the following phases. First, there is a shock to wages. Second, firms fully reflect the increase in costs in their prices. Third, all firms, given the assumed production function, increase their prices to reflect the increases in the cost of the intermediates that they use ([97]). These are then reflected in final demand.

III.3. THE ILLUSTRATIVE WAGE SHOCKS

As indicated above, the illustrative wage shock corresponds to an increase by 5% of nominal wages for the total economy ([98]).

Graph III.3: **Labour cost per sector (%), labour share over total economy(%) and forward linkages indicator**



(1) Wage costs are measured as the ratio between compensation of employees and total costs measured as total output minus gross operating surplus. Share of Labour costs are the share of labour costs of the sector over the total of the economy. The forward linkages indicator is the row sum of matrix G of equation (4) of the Box (see footnote 102).

Source: Eurostat and own calculations.

([95]) This assumes that the gross operating surplus is unchanged. If one considers that the gross operating surplus is equivalent to profits, this implies unchanged profits.

([96]) See Box III.1.

([97]) It should be noted that, in principle, the calculation of the indirect effect via the Leontief and Ghosh matrices represents the limit of an infinite number of interactions of decreasing size.

([98]) Under the assumption that social contributions are proportional to wages, this corresponds to a 5% increase in total compensation of employees (D1 in national account parlance).

As already stressed, the shock is purely hypothetical even if its magnitude broadly matches the cumulated fall in real wages observed between the latest peak in euro area real wages in Q2-2021 and their trough in Q2-2023.

As a first approximation to understand the sectoral dimension of a wage shock, the distribution of the ratio of labour cost over total cost and over gross output is represented in Graph III.3 (yellow bars). If one looks at aggregate data, labour cost of employees ([99]) constitutes on average around one quarter of total output in the economy (24%), and one third of total costs (30%). The variation of wage costs across sectors is relatively high: non-market sectors public administration and defence, compulsory social security (O), education (P), and human health and social work activities (Q) post labour costs higher than 55% of total costs and 50% of gross output; the sectors agriculture (A), electricity, gas, steam and air conditioning supply (D) and real estate activities (L) post labour costs at or below 15% of total costs and 10% of gross output.

The share of wages in costs is, however, likely not to be the total effect of the wage increase: as sectors raise their output prices, this will increase the cost input from other sectors, since sectors use each-other's outputs in their production as intermediate goods. The next sections go into more detail describing these sectoral interlinkages and discuss the methodology used to calculate the effect of wage increases of various sectoral profiles on inflation, taking into account both the direct and the indirect effects.

III.3.1. Three structural factors that determine the inflationary impact of wage shocks

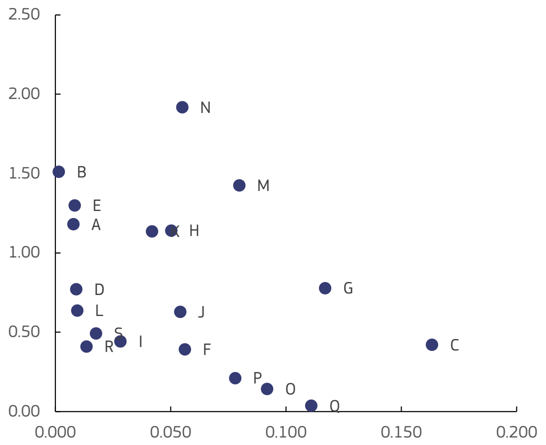
The direct impact on the consumer price index from the increase in the cost of labour described above depends on the size of the increase in wages and the aggregate labour cost share. However, to understand the full impact of a wage shock on total inflation other aspects than the direct increase in costs are important. The section focusses on the aspects concerning the structure of the economy.

Consider a shock that has a certain sectoral composition. On top of the share of cost that labour represents in each sector, the size of the sector with respect to the total economy, measured as the share of the sector's labour cost over the total labour cost of the economy is significant for the impact of the shock on the aggregate consumer price ([100]). A 1% increase in wages will have a greater impact on overall consumer prices if it affects a large sector than a small one, and the impact on prices will be greater the larger the share of costs represented by wages in that sector. The two indicators are correlated, but the correlation coefficient is only 0.4. The size of the different sectors is shown in Graph III.3. The graph plots the 19 main NACE sectors and shows that the manufacturing sector (C) is the largest sector in terms of labour costs with 16% of labour income of the total economy, followed by human health and social work activities (Q) and by wholesale and retail trade plus repair of motor vehicles and motorcycles (G) both with shares of 11-12%, followed by the sectors public administration, defence and compulsory social security (O) and education (P) just below 10%.

([99]) Total cost is measured as total output minus gross operating surplus. Therefore, for the purpose of the present exercise gross operating surplus are considered equivalent to profits.

([100]) Clearly the impact on the price of each sector depends also on the share that the given sector represents in consumption.

Graph III.4: **Forward linkages indicator and labour cost shares**



(1) Forward linkages index (see footnote 102) is on the Y-axis and labour cost shares are on the X-axis.

Source: Eurostat and own calculations.

However, in total market-oriented activities cover broadly two thirds of total labour costs of the economy. The smallest sectors are mining (B), where labour cost represents a very small share of total economy labour costs (0.2%), agriculture (A), and real estate activities (L), both below 1%.

Thus a 1% increase in wages in manufacturing is a shock that is around 20 times larger for the economy than a 1% increase in, say, agriculture.

The third relevant factor to assess the impact of a wage shock relates to the interlinkages between sectors of the economy ([101]). Increased labour costs in one sector, say A, when reflected in its prices, means that the costs of intermediates goods bought by sectors downstream from sector A increase and are then reflected in price and cost increases along the value chain to final demand. This implies that the same wage shock concentrated in sectors that provide greater inputs to the rest of the economy, has a larger impact on overall inflation. Sectors can be ranked according to a forward linkages index, which is higher for sectors having a greater impact on the economy, (i.e. for being more upstream in the value chain) ([102]). The index says by how much a 1EUR increase in wages in one sector increases production prices (under the stated assumptions) in the other sectors.

Graph III.4 compares this indicator for the different sectors along with labour costs. It shows that the sum of the responses of all other sectors to a EUR 1 increase in total labour costs in the administrative and support service activities (N) will be an increase of the value of total output by around EUR 2, while it will have an impact of only EUR 0.02 if this takes place in human health and social work activities (Q). In general, market sectors post larger values for the forward link index, pointing to positions more upstream in the chain, with the most upstream position (after sector N) being occupied by mining (B) and professional, scientific and technical activities (M).

Graph III.4 shows that the forward linkages index and the size of the sector in 2022 were negatively correlated, indicating that larger sectors seem to be in general nearer to the final demand in the supply chain. This implies that those two factors tend, to some degree, to balance each-other out in terms of the overall impact of any given shock ([103]).

([101]) To compute the linkages between sectors, the latest available Input-Output matrix (2019) has been projected forward to 2023 using national accounts data and maintaining the same shares of intermediate inputs (domestic and imported) as in 2019 as detailed in Box III.1.

([102]) The concept of (backward and) forward linkages has been introduced by Hirschman, A. (1958), “The Strategy of Economic Development”, Yale University Press. It is computed as the sum of the row coefficients of the matrix of equation (4) in the Box for the corresponding sector, deducting the self-consumption coefficient. Leaving the self-consumption coefficient in the calculation would not change the ranking significantly. A similar indicator can be created by adding up the of the direct output coefficient matrix (namely the input-out matrix named B in the Box). It should be noted that this section only considers direct links between sectors, but it abstracts from indirect links, like for example the dynamic relationship between public and private wages or the role of unions in driving inflation.

([103]) A word of caution on this analysis is that the size and the position of any given sector depend on the rules adopted by statistical offices to decide which companies belong to a sector and on the level of aggregation chosen. For example, manufacturing is a very large sector which contains upstream and downstream sub-sectors, while mining is smaller and its position in the value chain is likely to be less affected by the aggregation level.

III.3.2. Three different scenarios in the context of recent labour market developments

To show the relevance of the structure of the economy for the inflationary content of a wage shock, one needs to analyse various shocks to overall wages that have the same aggregate size but have a different sectoral composition. To this end, in this sub-section, three scenarios are presented. Each of them is consistent with the shock presented in the previous step, in that, the aggregate wage bill is increasing by 5%. However, these scenarios differ in terms of their sectoral composition. Keeping a constant increase in total labour costs is necessary to enable comparability among the three scenarios, even if one has to pay the price of taking into account very high wage increases in certain sectors (typically small ones) under one of the scenarios.

The three scenarios are presented in Table 1 of Box III.1 and their logic can be described as follows.

The first scenario is a scenario in which the increase in nominal wages is equal across the economy, namely to 5% in all sectors, as indicated above. While this size is purely hypothetical, it broadly corresponds to the increase in wages that would bring real compensation per employee back to its 2021 level in the euro area.

In the second scenario, while the total wage bill increase remains at 5%, nominal wage increase are differentiated across sectors so as to broadly reflect the relative sectoral differences in real wage losses since the recent surge in inflation. Indeed, since 2021 a larger reduction in real wages has taken place in market sectors B to E and in finance (K). Real wages in some non-market activities, e.g. in arts (R) and in other services (S), have decreased more moderately although they have decreased more strongly in the public sector. Against this background, the second scenario assumes faster wage growth in the sectors that have experienced larger losses in purchasing power since 2021 ([104]).

The third scenario reflects a situation in which all the recovery in real wages happens in the market sectors B to N, and it happens in proportion to labour market tightness in each of those sectors as indicated by the growth of the vacancy rate in recent years ([105]). This scenario reflects the strength of the labour market in the euro area (Graph III.5) and the existence of a positive relation between nominal wage increase and the vacancy rate (see Graph III.6).

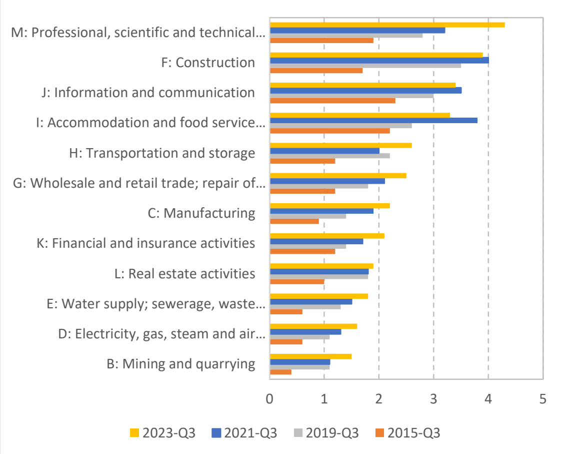
The euro area recently posted a broad-based growth in labour shortages, resulting in vacancy rates, that are close to their record levels in almost all sectors. However, while vacancy rates have been increasing in most sectors, Graph III.5 shows that there is a significant variation across sectors. Between 2019 and 2023, the strongest growth in the vacancy rates can be found in manufacturing (C); electricity, gas, steam and air conditioning supply (D), wholesale and retail trade, repair of motor vehicles and motorcycles (G), financial and insurance activities (K) and professional, scientific and technical activities (M). In the post-pandemic period (2021-2023) mining and quarrying (B), water supply, sewerage, waste management and remediation activities (E) and transportation and storage (H) also experienced a relatively strong growth in vacancy rates.

Across sectors, wage growth has shown a strong association with pre-pandemic vacancy rates ([106]). Cumulative wage growth since the beginning of 2019 was higher in sectors that experienced higher vacancy rates in the pre-pandemic period (Graph III.6) ([107]).

([104]) For the purpose of the simulation, we look at the peak decrease in real wages, namely the decrease that took place between Q3-2021 and Q3-2023.

([105]) Details on the computation of this shock are given in Box III.1.

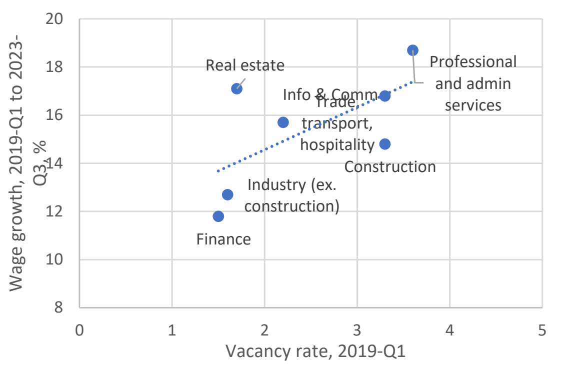
([106]) In particular, the cross-sectional association suggests that a sector in which the vacancy rate was 1 ppt higher pre-pandemic experienced higher wage growth by about 0.5 ppt annually over the four subsequent yearsIt is prudent to look at this longer period since wage growth over the pandemic period was hard to interpret, being affected by fluctuating hours worked (related to pandemic containment measures) as well as government measures to cushion the impact of the pandemic. See, e.g., Bodnar, K., Gonçalves, E., Graph III.5: **Job vacancies by sector**



(1) Job vacancies are shown for Q3 at different years. Q3-2023 was the peak quarter for vacancies.

Source: Eurostat (Job Vacancy Survey) and own calculations.

Graph III.6: **Nominal wage growth (Q1-2019 - Q3-2023) and the vacancy rates (Q1-2019) across sectors**



(1) Wage growth is compensation of employees with per capita adjustment by sectorial employment. Compensation is seasonally and calendar adjusted where possible. Vacancy rates are unadjusted.

Source: Eurostat and own calculations.

This pattern is likely to be related to labour demand dynamics since cumulative wage growth tended to be higher in sectors that added more employment (not shown). The third shock is therefore built by allocating the 5% increase in total compensation of employees across those sectors in proportion to the observed increase in vacancy rates (see Box III.1). Wages in non-market sectors are assumed to remain constant. This assumption is not realistic. It is therefore important to stress the illustrative nature of the shock, but its features help to stress the various direct inflationary impact between wage increases in market and non-market sectors.

III.4. THE RESULTS

The direct effect of an increase in labour costs of 5% represents an increase in total costs of around 1.5% and of 1.2% in total output. If firms fully reflect such an increase in their prices, leaving everything else unchanged, this will generate a direct increase in output prices of the order of 1.2% ([108]). This is smaller than the impact of a wage shock on the gross value-added deflator. Compensation of employees is around 53% of gross value added. Therefore an increase in wages by 5% would imply, all

Gornicka, L. and G. Koester (2022) "Wage developments and their determinants since the start of the pandemic",ECB Economic Bulletin, Issue 8/2022, European Central Bank, Frankfurt.

([107]) The existing literature finds that indices of labour market tightness correlate positively with wage growth notably in low-pay sectors, despite the fact that tightness has so far play a limited role in contributing to wage acceleration. See Duval, R. Ji, Y. Li, L. Oikonomou, M. Pizzinelli, C., Shibata, I., Sozzi, A. and M. M. Tavares. (2022). Labor market tightness in advanced economies. IMF Staff Discussion Notes 2022/1, Washington D.C.

([108]) The wage ratio increases by almost 10 ppt of value added if one includes in compensation of employees the wages earned by self-employed (imputed wages), which are recorded as mixed income and are part of the gross operating surplus. Given the illustrative mature of the exercise, the imputation is not done here.

other things being equal, an increase in the GDP deflator by around 2.7%. The larger size generated by using the GDP share results from the fact that, in this case, the presence of the intermediate costs, which are around 60% of the total costs paid by the sector are ignored, thus magnifying the impact of a wage increase on costs and thus on prices.

The three scenarios presented in the previous section show how the differing sectoral composition of a wage shock of the same size changes its impact on consumer prices. Table III.1 shows the impact on consumer prices under the three scenarios.

Under the first scenario, where wages grow by the same amount in each sector, the impact on consumer prices is simulated to be at 1.9%. As expected, the total price effect in this scenario is larger than the direct effect of the initial increase in wages on consumer prices, as the wage shock is propagated through the economy via the sectoral inter-linkages. The indirect effects increase the direct effect by around a half. However, it is interesting to notice that, even taking into account the indirect effects, the impact of a wage shock on final consumer prices is just less than one third of the size of the initial wage shock. The impact is also smaller than the direct impact on the GDP deflator. The use of input-output models is the only way to correctly assess the effect of a wage increase on consumer prices, even more so if the wage increases are concentrated by sector as shown below. Indeed, the three shocks, despite having the same aggregate size, have a different impact on inflation.

Table III.1: **Increase in consumer prices (%) under the three scenarios**

Scenario 1	Scenario 2	Scenario 3
1.9%	1.8%	2.8%

Source: Own calculations.

In the second scenario, there happens to be a slightly negative correlation of the shock, measured as the percentage increase in wages, with the forward linkage index (-0.1). This implies that the second scenario simulates slightly larger increases in more downstream sectors, and the overall impact is 1.8%, marginally smaller than in the first scenario. The very small correlation between the forward linkages index and the shock points to a certain similarity between the two first scenarios, but this is enough to decrease the impact in proportion to the total inflation effect.

A clearer indication of the importance of the presence of forward linkages is given by the third scenario. In this scenario wages in the market sectors (except agriculture) increase proportionally more in the sectors with higher labour market stress, while wages in the non-market sectors remain constant. The correlation between the shock and the forward linkages index is positive (0.5) reflecting the fact that more stressed sectors tended to be upstream sectors. This scenario is relatively different from the uniform scenario, in that a considerably larger shock is given to wages of upstream sectors. In this case the simulated increase in inflation is just below 3%, a considerably larger amount than the previous cases ([109]).

([109]) It should be noted that the second shock posts a small positive correlation between the share of labour cost represented by the sector in the total economy and the assumed sectoral increase in wages (0.2) while in the third shock the correlation between the shock and the size of the sectors is negative (-0.3), reflecting the fact that most stressed sectors were smaller sectors. This does not affect the result, most likely because the size effect is accounted for by assuming the same economy-wide shock.

Box III.1: **Methodological framework for sectoral wage shock analysis in the euro area**

This box explains the simulations' methodology used in the text. Simulations are based on input-output (I-O) models. In the I-O model, the production output of each sector (o) is determined as a function of intermediate consumption, domestic (Z) and imported (M) and its value-added components (v). Value added is composed by Compensation of Employees (w), Taxes (t) and Gross Operating Surplus (gos). To establish the notation, one can write

$$o = Z^{'}i + M^{'}i + v; \quad v = w + t + gos \tag{1}$$

In this text, lower-case letters denote vectors, upper-case letters represent matrices. In Equation (1) $Z^{'}$ is Z transposed, and i denotes a unit vector.

Data

Data for these variables at the chosen sectoral decomposition for the euro area (1) are available at different dates. Precisely, these data for the euro area can be sourced starting from 2022 national accounts (2) and the 2019 I-O table (3):

- Intermediate consumption. Recent data by sector on intermediate consumption are not available. However, one can compute the 2022 aggregate intermediate consumption data by subtracting value added from total output (P1) from national accounts and then allocate them between imported and domestic intermediate consumption and between the different sectors. Precisely, the entries of the domestic intermediate consumption matrix were found by applying the shares of the sectoral consumption on the total intermediate consumption as in the 2019 I-O table. The same approach was employed for the matrix of imported intermediate goods.

- Value-added components. Value added data by NACE sector for 2022 are available from national account. w (D1), as Compensation of Employees, are available. t were estimated as the same proportion of total value added (B1G) as in the 2019 I-O table (4). gos (B2A3G) were subsequently determined by subtracting the sum of the wages and taxes from the total value added for 2022.

The computation of the shocks

The starting point for calculating the shocks is a 5% nominal wage growth per employee for the total economy. This is used directly to compute the shock in the first scenario. The second scenario allocates a shock of the same aggregate size broadly in proportion to the decrease in real wages in the different sectors between 2021-Q2 and 2023-Q2. Nominal wages by sector are computed as the difference between the percentage change of compensation of employees divided by the number of employees at the quarterly frequency. Real wage growth was computed by subtracting HICP from nominal wages growth.

(1) The sectoral breakdown corresponds to the 21 sectors of "NACE 2.1" classification, available at: ShowVoc (europa.eu).
(2) The most recent data for the euro area at sectoral level for output (P1), intermediate consumption (P2), value added (B1G) and compensation of employees (D1) are, at the time of the analysis, 2022 data available in national accounts: Statistics | Eurostat (europa.eu). Starting from these data and using the shares retrieved from the 2019 I-O table, it is possible to imply domestic/imported intermediate consumption and specific value-added components for 2022.
(3) The 2019 I-O table was selected, despite 2020 being the latest available year at the time of analysis, to prevent the distortion effects of COVID-19 in subsequent years' estimates. The 2019 I-O table is available at: Statistics | Eurostat (europa.eu). This I-O table presents a sectoral breakdown of 64 sectors, which have been grouped to match the 21-sector aggregation proposed in this analysis.
(4) Taxes are not directly available in national accounts of 2022, thus requiring the explained computation under the assumption that tax shares over VA are constant over time.

(Continued on the next page)

Box (continued)

Table 1:

NACE sector	Scenario 1	Scenario 2	Scenario 3
Agriculture, Forestry and Fishing (A)	5%	3%	0%
Mining and Quarrying (B)	5%	7%	6%
Manufacturing (C)	5%	7%	8%
Electricity, Gas, Steam and Air Conditioning Supply (D)	5%	7%	8%
Water Supply; Sewerage, Waste Management and Remediation Activities (E)	5%	7%	8%
Construction (F)	5%	5%	6%
Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles (G)	5%	4%	8%
Transportation and Storage (H)	5%	4%	7%
Accommodation and Food Service Activities (I)	5%	4%	8%
Information and Communication (J)	5%	7%	7%
Financial and Insurance Activities (K)	5%	8%	8%
Real Estate Activities (L)	5%	6%	5%
Professional, Scientific and Technical Activities (M)	5%	3%	9%
Administrative and Support Service Activities (N)	5%	3%	6%
Public Administration and Defence; Compulsory Social Security (O)	5%	6%	0%
Education (P)	5%	6%	0%
Human Health and Social Work Activities (Q)	5%	6%	0%
Arts, Entertainment and Recreation (R)	5%	2%	0%
Other Service Activities (S)	5%	2%	0%

The shock for the third scenario aims at reflecting the tensions in the sectoral labour markets, also weighted by the size of the sector. It is computed as follows. First, changes in the vacancy rates over the quarters between 2019-Q3 to 2023-Q3 for the market sectors excluding agriculture are computed. Even if we are aware that wages and labour market data for 2020-21 can be distorted by the presence of job retention schemes, we still prefer to keep a longer series, as explained in the text. The vector of increases in vacancie rates is multiplied times the vector of share of compensation of employees, thus creating the basis for a weights vector. The latter is then normalized to generate a weights vector whose elements sum up to 1 that can be used to allocate the shock across sectors. Second, the 5% increase in the aggregate wage bill is allocated to the sectors using as an allocation key the weights' vector. Table 1 details the shocks applied to each sector under the three different scenarios:

The calculations

The Ghosh version of the input-output model provides a general framework for analyzing both the direct and indirect impacts of input shocks on sectoral output prices. The difference with the traditional Leontief input-output model is that, while in the Leontief model the production coefficients are set, i.e. the ratio of the inputs used in each sector divided by the output of the sector, the Ghosh version sets the ratio of the demands for the output of each sector. The two models have different pros and cons, with the Ghosh model being used to analyse how a shock to inputs in one sector spreads on downstream sectors, while the Leontief version is used to analyse how demand shocks are transmitted to upstream sectors. Yet, when assuming that the only shocks concern prices, the results of the two give identical results ([5]). Following Výškrabka and Zeugner (2023) ([6]), Equation (2) ([7]) introduces the matrix B, where each cell in a given row is the ratio of the rows of Z divided the corresponding row total output o. Equation (3) sets total output. Equation (4) defines the Ghosh inverse.

(5) For more details see Chapter 12 of Miller R. E. and Blair P. D. (2009), "Inpu-Output Analysis. Foundations and Extensions", Cambridge University Press, second edition.
(6) Výškrabka M. and Zeugner S. (2023), "Inflation spillovers in the euro area in an input-output framework", European Commission.
(7) In the notation of matrix algebra, placing a "hat" (^) over a vector symbol indicates the creation of a diagonal matrix, wherein the elements of the vector are positioned along the main diagonal.

(Continued on the next page)

Box (continued)

$$B = \hat{o}^{-1} Z \tag{2}$$

$$o = B^{'} o + M^{'} i + v \tag{3}$$

$$G = (I - B')^{-1} \tag{4}$$

$$o = \mathrm{G}'(\mathrm{v} + M'i) \tag{5}$$

The Ghosh inverse allows to compute a detailed decomposition of variations in the output prices by tracing them back to the contributions of changes in costs of production inputs, under the assumption of perfect additive pass-through—where the total increase in the output precisely matches the aggregate increase in input costs— which allows to directly link observed shifts in output prices with changes in wages. Equation (5) can be reformulated in terms of changes to show how changes in wage costs drive adjustments in gross output prices as:

$$\Delta o = G'(v\, \widehat{Dw}) \tag{6}$$

$$o^{*} = \Delta o + o \tag{7}$$

In equation (6) Dw represents the vector of the shocks to wages, which is computed as the product of the sectoral wage growth rate, chosen as detailed above, times the starting value of the compensation of employees. Δo is the increase in prices under the simulation and o^{*}represents the the value of output at basic prices computed under the new set of wages.

In order for the model to be fully coherent, it is necessary that the final demand respects the identity which establishes that total domestic output is equal to the sum of the uses, namely the sum of the value of output which is used as intermediate good plus the output which is used to satisfy the final demand in each sector. This is obtained via Equations (9) and (10) below

$$A = \hat{o}\; B\; \hat{o}^{-1} \tag{8}$$

$$f = (\mathrm{I} - \mathrm{A})\; o \tag{9}$$

$$f^{*} = (\mathrm{I} - \mathrm{A})\; o^{*} \tag{10}$$

$f^{*} - f$ is interpretable as the increase in prices per sector. Finally, to compute the aggregate increase in consumption prices, the increases in prices per sector (in percentage) are aggregated using as weights the weights of the vector consumption.

III.5. CONCLUSIONS

Overall, simple simulations with an input-output model confirm the findings of the literature that the increase in consumer prices generated by the impact of wage shocks are considerably smaller than the original shock. As such they are unlikely to generate situations in which a wage shock triggers a wage price spiral. This is because the share of wage costs in total production costs is relatively low.

While labour costs represent around one third of total costs, taking into account the second-round effects can significantly increase the impact of a wage shock on consumer prices. The most interesting result of the chapter is that such second round effects can be relatively large depending on the (size and) position of the sector in the interlinkages map of the economy. Shocks originating in larger and more upstream sectors have a substantially larger impact than shocks originating in smaller and downstream sectors. This means that, in the present situation, a scenario in which workers in all sectors obtain the same increase in wages would have a smaller inflationary impact than a shock of the same aggregate size but restricted to the more upstream market sectors.

The results presented in this chapter are based on very stylised illustrative scenarios. Many factors that play an important role in inflation dynamics, including other cost shocks and inflation expectations, are not modelled here. Nevertheless, the analysis presented here can be useful for forecasters as it provides a tool to estimate with more accuracy the inflationary implications of a given nominal wage growth scenario. In its Spring 2024 forecast, the Commission expects real wages to recover by 2025 their 2021 level, driven by moderately increasing wages and further slowing of inflation. Against the background of partial reversal of the positive labour demand and supply shock of the past few quarters and subdued growth prospects for the beginning of 2024, it seems likely that such an increase in real wages will happen while inflation continues to stabilise. This illustrates that inflation is driven not only by wage cost dynamics but also by other factors (notably other cost factors including energy). Finally, the push to nominal wages is projected to be very gradual, and smaller than the illustrative choice made in this chapter for clarity purposes. This would imply smaller second-round effects and a reduced inflationary impact.

ANNEX. A CHRONOLOGY OF THE EURO FROM ITS ORIGINS TO ITS 25TH ANNIVERSARY

As 25 years ago, on 1 January 1999, the euro was launched in 11 Member States, this chronology recalls the euro's history since its origins. It shows the intrinsic links of monetary unification with the Single Market and the experience of the previous currency arrangements. The euro delivered significant benefits to the economies in the euro area, which has meanwhile expanded to 20 Member States, and it is a tangible symbol of the European identity and prosperity. The euro helped its members in 'weathering the storms' of various crises during its first 25 years that also paved the way towards a stronger governance, making the euro area more resilient.

The origins

The project of a single currency for Europe was in great part motivated by the aim of implementing the single market. The first steps towards creating a single market in the EU date back to the 1957 Treaty on the European Economic Community (EEC), with the agreement to form a customs union among the six signing Member States ([110]). The project was further developed by the Single European Act of 1986 reforming the EEC Treaty, which declared end-1992 as the target date for implementing a single market with free movement of goods, services, capital and labour within the EU. Against this background, exchange rate fluctuations among Member States' currencies and the possibility of competitive devaluations would be detrimental to trade and financial flows and were seen as a potential threat to the single market. A single currency would achieve the objective of eliminating such fluctuations, with benefits that would go beyond economics, as a tangible symbol of European identity and prosperity, further deepening integration. The 1990 Commission study on economic and monetary union, called 'One Market, One Money', reflected these intrinsic links between economic integration and monetary unification.

The currency arrangements of the 1970s were key steps towards more exchange rate stability and paved the way for closer monetary integration in the EU. The first specific proposals for creating a European monetary union in several stages (1969 Barre Plan, 1970 Werner Report) were not further pursued due to the collapse of the Bretton Woods system and the oil price shock in the early 1970s. Instead, in 1972, an intermediate step was agreed, aiming to keep the fluctuations of exchange rates between European currencies within certain limits ('European currency snake'). In 1979, another important step towards closer monetary integration was taken with the creation of the European monetary system (EMS) and its exchange rate mechanism (ERM), pegging participating currencies to the European Currency Unit (ECU) ([111]).

In 1989, the Delors Report reflected the awareness that national monetary policies and fixed exchange rates would be incompatible with the free movement of capital. A study led by Tommaso Padoa-Schioppa, on the implications of the single market for the future of the EEC, warned that liberalised capital movements as part of the single market were inconsistent with the objectives of exchange rate stability and autonomous national monetary policies ('the impossible trinity' as developed by the economists Fleming and Mundell in the early 1960s). In June 1988, in Hanover, the EU Heads of State or Government mandated a committee, mainly composed of central bank governors with Padoa-Schioppa as rapporteur and chaired by Jacques Delors, to prepare a report on European economic and monetary union (Delors Report of April 1989). The report proposed, in further detail, a process in three stages, building on the ideas of the Werner Report. In the background, economists were also exploring the conditions that should be in place in countries forming a monetary union ('optimum currency area' theory). In December 1990, the EU Heads of State or Government launched intergovernmental

([110]) Belgium, Germany, France, Italy, Luxembourg and the Netherlands.

([111]) The ECU was only a unit of account and not a currency yet, whose value was calculated as a basket of the currencies participating in the ERM. It did not replace national currencies and its practical use was limited.

conferences to revise the Treaty along these lines, as well as other policies, which culminated in the Maastricht summit in December 1991.

The Maastricht Treaty, which was signed in February 1992 and entered into force in November 1993, laid the legal foundations of the European Economic and Monetary Union (EMU) on the basis of the proposals in the Delors Report. Stage One (1 July 1990 to 31 December 1993) aimed to remove barriers to the free movement of capital within the EU, improve coordination of economic policies, and strengthen cooperation between central banks. Stage Two (from 1 January 1994) aimed to set up the European Monetary Institute, prepare the introduction of the single currency, and bring about convergence of policies to ensure stable prices and sound public finances (the Maastricht convergence criteria). Stage Three (by 1 January 1999 at the latest) aimed to set conversion rates between the national currencies and the single currency, transfer monetary policy powers to the independent European Central Bank (ECB), and introduce the single currency. The United Kingdom – and later Denmark – had negotiated special conditions and would not be legally obliged to adopt the euro ([112]).

A succession of ERM crises in 1992-1993 strengthened the case for monetary unification. These crises showed how fixed or managed floating exchange rates would always remain fragile and exposed to market pressures. Among the underlying reasons were the inflationary pressures and investment needs following German reunification, coupled with Germany's central role in the ERM. The Bundesbank increased its policy rates, triggering capital inflows and upward pressure on the value of the Deutschmark and conversely downward pressure on the currencies of other ERM countries, which were required to take unilateral action to stay within the ERM bands. This fundamental asymmetry in the system, coupled with speculation, led to the collapse of the system. The UK pound exited from the EMS in September 1992, while the central parities of several other currencies in the ERM had to be realigned and the fluctuation bands were substantially widened to stall further speculative attacks. In subsequent years, policy action to meet the convergence criteria of the Maastricht Treaty (on sound public finances and stable prices and exchange rates) supported Member States' commitment to exchange rate stability.

The single currency was baptised 'euro' at the Madrid summit in December 1995. With the memory of the ERM crises still fresh, the Madrid summit was crucial to overcome internal differences between Member States as to their readiness to launch the EMU by 1999, while acknowledging that the initial launch date of 1997 could not be met. The name 'euro' for the single currency was agreed, a more popular name and easier to pronounce in all languages than that of its predecessor, the ECU.

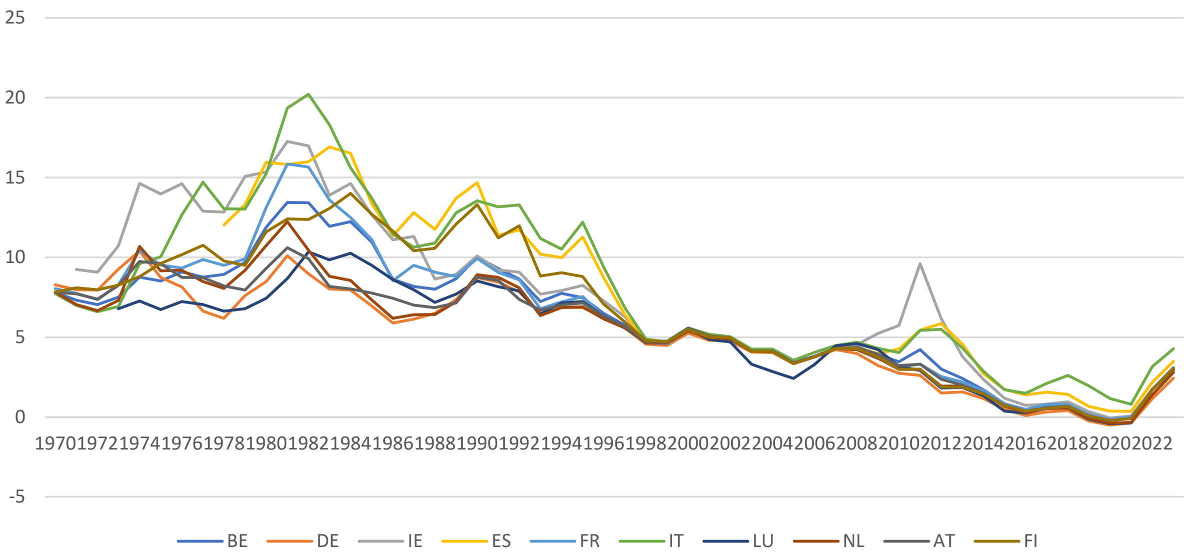
The years of fast integration and convergence

On 1 January 1999, the euro was born and set to grow fast, and the ERM gave way to the ERM II as a gateway for future euro area members. At that moment, the currency conversion rates of the initial 11 participating countries ([113]) that had met the convergence criteria as laid down in the Treaty were fixed and the euro replaced the ECU on a one-for-one basis, representing in practice a basket of euro area currencies. The ECB, which had been set up in mid 1998 – replacing the European Monetary Institute – and was following the model of the Bundesbank, including its independence, was given the responsibility for a single monetary policy with the primary objective of price stability. While initially the euro could only be used as an accounting currency and for electronic payments, the introduction of euro banknotes and coins in the participating 12 countries (as Greece had joined the initial group of 11 countries) followed on 1 January 2002. Another eight Member States would join the euro between 2007 and 2023, following their successful participation in ERM II and having met the

([112]) The UK eventually left the EU in 2020 after a referendum in 2016.

([113]) These were the currencies of Belgium, Germany, Ireland, Spain, France, Italy, Luxembourg, The Netherlands, Austria, Portugal and Finland. Greece joined the euro in 2001.

Graph Annex.1: **Convergence of long-term interest rates in the euro area**



(1) 10-year government bonds yield (according to the Maastricht criterion) reference rate, based on government bonds with a maturity close to 10 years.

Source: AMECO.

convergence criteria for joining the euro (114). The euro soon became the second-most used international currency after the US dollar, and several countries outside the euro area have pegged their currencies to the euro. In 2023, the single currency covered nearly 350 million people (close to 80% of the EU population).

The monetary union was not accompanied by a fiscal union. Unlike the United States of America, the EMU was set up without a common fiscal policy that could act as a mechanism of adjustment to smoothen asymmetric shocks across participating countries. Rather, the Maastricht Treaty further specified the legal basis for EU surveillance of Member States' economic policies, in particular with respect to the reference values for budget deficits (3% of GDP) and public debt (60% of GDP) (Art. 126), and for the broader coordination of economic policies (Art. 121). The fiscal constraints set by the Treaty were to ensure that Member States themselves would have the fiscal capacity to respond to shocks on an individual basis. The Treaty's rules for ensuring compliance with these criteria were further specified in the Stability and Growth Pact that was agreed in 1997 and continued to develop in the following decades.

The first decade of the euro already delivered significant benefits to the economies in the euro area. It was a period of solid economic growth, in particular in participating countries with lower income per capita, allowing them to converge towards those with a higher income. The ECB's monetary policy ensured price stability, also by credibly anchoring inflation expectations to its 2% target from the outset. The burst of the 'dot com' bubble in early 2000 also showed the benefits of being in a monetary union as the financial fallout was limited and the usual volatility of exchange rates in such situations was no longer possible among euro area countries.

(114) Slovenia (2007), Cyprus and Malta (2008), Slovakia (2009), Estonia (2011), Latvia (2014), Lithuania (2015), and Croatia (2023).

Weathering the storms

In 2008-2013, a succession of economic crises showed the weaknesses in the governance of the euro area but also its readiness to act in solidarity. When the global financial crisis (GFC) started in the US in 2007, there was quite some optimism that the consequences for Europe would be limited ('decoupling hypothesis'). Unfortunately, this assessment turned out to be wrong. The exposure of European banks triggered a credit crunch that impacted negatively on the highly leveraged private and public sectors of a number of euro area countries and further exposed banks, requiring government bailouts of the banking sector (the 'doom loop'). The risks associated with the build-up of high private and public sector debt in some Member States became fully visible. These risks had been largely ignored in the first decade of the euro as a natural by-product of financial integration and convergence. Now, the euro area was faced with a widening of spreads among sovereigns (and, by extension, among private issuers of different countries) to an extent that would eventually cut some of them off from international capital markets and cause financial fragmentation. Financial assistance was provided to Greece, Ireland, Portugal and Cyprus, as well as to Spain specifically to re-capitalise banks, coupled with a policy agenda to address the country-specific underlying causes of the crisis. To finance these assistance programmes, euro area Member States initially created several financial stability instruments that were mostly intergovernmental arrangements, notably in the form of the Greek Loan Facility (GLF, 2010) and the European Financial Stability Facility (EFSF, 2011). In 2013, the European Stability Mechanism (ESM) was created as a permanent mechanism to fund macro-financial assistance in the euro area. The ECB's monetary policy response helped resolve the crisis, delivering on a commitment by ECB President Mario Draghi in July 2012 that its institution would do 'whatever it takes' to save the euro area.

Alongside these developments, the euro area and the EU underwent the first major overhaul of their governance framework. In 2010, the European Semester was created to provide a more integrated approach to EU policy coordination, with country-specific recommendations for Member States to guide their policies, reforms and investments. The intergovernmental Treaty on Stability, Coordination and Governance (2011, 'Fiscal Compact') added further requirements related to the surveillance of fiscal and structural policies and created the Euro Summit. Additional legislation was adopted to strengthen the Stability and Growth Pact and budgetary frameworks in Member States and to extend the scope of economic surveillance via the Macroeconomic Imbalance Procedure (the 'six-pack' legislation in 2011 and the 'two-pack' in 2013).

The calm after the storms

The period following the GFC and the euro area sovereign debt crisis was characterised by policy action to support growth and fight the risk of deflation. Interest rates at the 'zero lower bound' facilitated debt deleveraging in high-debt countries, and the ECB followed other major central banks in providing liquidity to the economy through unconventional monetary policy and quantitative easing ([115]). The European Fund for Strategic Investments (EFSI, also called 'Juncker Plan', 2015) was launched to support investment and lift productivity; the predecessor of InvestEU. In this period, major structural reforms at Member State level took place, including in areas such as insolvency, labour markets, and pensions. Economic growth strengthened from 2015 onwards as the policy reform agenda in the euro area and the EU started to bear fruits, including a strengthening of banks' balance sheets and an improved performance of labour markets.

There was also a renewed ambition and continuous effort to deepen the EMU. Most initiatives were based on proposals in the Four Presidents' Report of December 2012 and in the Five Presidents' Report of June 2015 as well as the Commission's white paper on completing the EMU of March 2017.

([115]) In this period, the ECB deployed targeted longer-term refinancing operations (TLTROs), with a first series announced in June 2014, to provide banks long-term funding at attractive conditions. In October 2014, the ECB launched its Asset Purchase Programme (APP) in October 2014, also with the aim of providing liquidity to the economy. This programme lasted until June 2023.

Some of the proposed additional steps for completing the Banking Union (BU) progressively became reality, in particular with the creation of the Single Supervisory Mechanism (SSM) and the Single Resolution Mechanism (SRM), but proposals for a European deposit insurance scheme, concrete steps to implement the Capital Markets Union (CMU) or initiatives to create a central fiscal capacity at EMU level did not gain similar traction.

Resilience in a poly-crisis world

When the COVID-19 pandemic started in early 2020, the euro area benefited from past reforms and lessons learned, and was able to respond swiftly and in a coordinated manner. The EU and the euro area were quickly faced with the risk of fragmentation and related lasting damage to the single market and to medium- and long-term growth prospects. To avoid repeating the hysteresis effects of high unemployment, collapsing investment and non-performing debt experienced in the aftermath of the GFC, this time there was an unprecedented coordinated EU policy response to safeguard jobs and incomes. The activation of the general escape clause in the Stability and Growth Pact gave Member States more flexibility for their own policy response and related spending. In addition, there was a better coordination of fiscal and monetary policy. The ECB deployed its pandemic emergency purchase programme (PEPP) and set up a Transmission Protection Instrument (TPI) to avert risks of financial fragmentation. The EU-level response included, among other things, the provision of substantial financial support through the temporary Support to mitigate Unemployment Risks in an Emergency (SURE) and the launch of NextGenerationEU to finance the Recovery and Resilience Facility (RRF). These measures led to a strong recovery of the euro area economy in 2021-2022, with virtually unscarred labour and credit markets, also benefiting from previously implemented reforms. When Russia started its unprovoked war of aggression against Ukraine in February 2022, another crisis hit, coming along with high energy and food prices and ensuing high inflation. This time around, the framework for coordination was already in place, and Member States were able to continue to support their economies. At the same time, the ECB showed commitment to pursuing price stability and maintained inflation expectations well anchored.

More united to face the challenges ahead

On approaching the euro's 25th birthday, significant steps have been taken to prepare the EMU for the challenges ahead, including another reform of its governance and initiatives that will boost the resilience of the euro. In 2022, work on the economic governance review, launched in 2020 but interrupted by the pandemic, was resumed. The Commission presented its legislative proposals in 2023 and an agreement among the co-legislators was reached in February 2024. In the course of the year, Member States are to design and present medium-term fiscal structural plans that set out their net expenditure path and their reform and investment strategies. The central objective is to strengthen public debt sustainability while promoting sustainable and inclusive growth in Member States by facilitating reforms and investment in common EU priorities. Further, in 2023, the Commission presented a proposal for the legal framework of the digital euro, and the ECB concluded its investigation phase. Supplementing euro banknotes and coins, the digital euro will ensure that people and businesses have an additional choice – on top of private sector options – that allows them to pay digitally with a widely accepted, cheap, secure and resilient form of public money in the euro area. In addition, there is a renewed impulse to deepen the CMU as a crucial tool to pool the necessary funding to strengthen the euro area's competitiveness, to secure the green and digital transitions, and to strengthen the international role of the euro.

Graph Annex.2: **Overview of the euro's history**

#EURO at25

Key milestones of the euro

1958	Treaty on the European Economic Community (6 Member States)
1968	Customs union completed
1969-1970	Barre plan and Werner plan proposing a way towards European Monetary Union (EMU)
1979	European Monetary System
1986	Single European Act
1989	Delors Report
1992-1993	Maastricht Treaty; completion of the Single Market (with four freedoms of goods, services, labour and capital in the 12 Member States)
1995	Madrid Summit with key decisions on EMU
1997	Stability and Growth Pact
1998	The European Central Bank becomes operational on 1 June
1999	Launch of the euro in 11 Member States
2001	Greece adopts the euro
2002	Introduction of euro banknotes and coins in 12 Member States
2007	Slovenia adopts the euro
2008	Cyprus and Malta adopt the euro; global financial crisis
2009	Slovakia adopts the euro
2010-2013	Euro area sovereign debt crisis and policy responses (e.g. financial assistance programmes financed by EFSF/ESM)
2011	Estonia adopts the euro
2014	Latvia adopts the euro
2015	Lithuania adopts the euro
2023	Croatia adopts the euro; Commission proposals to protect cash and enable the possible creation of a digital euro

Source: European Commission, DG ECFIN's staff.

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