Network for Greening the Financial System

Technical document

# The macroeconomic effects and monetary policy implications of climate mitigation policies: results from a new quantitative analysis

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# Foreword

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*Government policies to address climate change have macroeconomic effects over the monetary policy horizon. In the past, the NGFS has reviewed the emerging evidence on how the transition to net zero could affect the macroeconomy and outlined the channels of impact, focusing on the effects on output and inflation.*

*This report makes an important new contribution by quantifying these effects, with a key focus on monetary policy trade-offs that can emerge in the short term during the phase-in of transition policies. Drawing on the IMF's Global Macroeconomic Model for the Energy Transition (GMMET), the analysis considers differences across sectors and regions as well as the interplay between carbon pricing, subsidies, and regulation. It also highlights the importance of credible and predictable policy frameworks in shaping macroeconomic effects on key variables including inflation, output and investment.*

*The report considers two policy scenarios under which countries seek to achieve greenhouse gas emission reduction targets in line with their nationally determined contributions (NDCs). These compare the macroeconomic effects in a scenario where countries focus on carbon pricing alone with the impacts of a broader policy mix which also includes green subsidies and regulation.*

*Mitigation policies are essential for reducing emissions and thus avoiding the worst damages from physical climate change. However, the findings show that they can generate short- to medium-term trade-offs for monetary policymakers by simultaneously increasing inflation and weighing on activity. These outcomes vary across regions depending on economic structures, carbon intensity, and policy ambition.*

*The analysis shows that, if carbon prices aligned with the NDCs are implemented in a gradual and orderly manner and monetary policy responds in a credible and predictable manner, then inflationary impacts may be limited. However, inflationary impacts can be higher if climate policies are not fully credible, or agents lack perfect foresight or are uncertain about their implementation. More generally, abrupt implementation of ambitious transition policies could generate short-term inflationary pressure, which monetary policymakers would need to manage.*

*We are grateful to the NGFS members and observers and the colleagues in the NGFS Secretariat who contributed to this work. Our special thanks go to the IMF modelling team, and colleagues from the Swiss National Bank and Bank of England who co-led this initiative. This analysis will support central banks in enhancing their understanding of the macroeconomic effects of the green transition, and their monetary policy implications.*

# Executive Summary

## The contribution of this report

**Climate change and the transition to net zero can affect macroeconomic outcomes over horizons relevant for monetary policy, as previously shown by the work of the NGFS Workstream on Monetary Policy (NGFS 2024).**

**When it comes to climate change and the transition, central banks take developments in the science of physical climate change and in governments' climate policies as given.** Their role is to understand, assess, and respond to the implications of these developments for the macroeconomy and the financial system insofar as they fall within their mandates. There is a wide scientific consensus (supported by the work among others of IPCC, IEA and NGFS) that delivering an orderly transition to net zero by 2050 minimises disruption and risks to the macroeconomy and the financial system. In order to achieve their price and financial stability mandates, central banks need to understand the impacts of the transition (or the lack of it) as it unfolds.

**This report provides a quantitative assessment of how mitigation policies can affect the macroeconomy over horizons relevant for monetary policy using the IMF's Global Macroeconomic Model for the Energy Transition (GMMET). It shows that the net zero transition can create monetary policy trade-offs as mitigation policies are phased in.** As carbon prices rise and regulations and subsidies shift economic activity towards lower-carbon alternatives, relative prices change and some production processes become more costly in the near term. The analysis explores how results may differ across different scenarios and modelling assumptions. They illustrate how macroeconomic outcomes depend on both the overall ambition of the transition and the choice of the government policy instruments. While transition policies can generate near-term trade-offs, they generate the benefits of avoided damages from climate change over the medium to long run (see Annex 1).

**As climate change itself intensifies, climate inaction also represents an important change in current macroeconomic conditions.** While this report does not focus on the macroeconomic impacts of inaction, it holds valuable insights for how macroeconomic impacts could differ the longer the transition is delayed, if it is then implemented abruptly. In particular, analysis shows that the greater the gap between where countries are and where they need to be to meet their Paris Agreement commitments, the more severe the macroeconomic impacts can be. This again underscores the importance of an early, orderly and gradual transition.

## What the model does

**The report provides a quantitative assessment of the macroeconomic effects of the transition and monetary policy trade-offs they may generate using the IMF's Global Macroeconomic Model for the Energy Transition (GMMET).** Over ten-year horizons it compares two scenarios, both of which result in emission reductions in line with countries' Nationally Determined Contributions (NDCs), but which differ in the manner with which these reductions are achieved. The first scenario achieves NDC targets primarily through economy-wide carbon pricing with revenues recycled to households. The second scenario reaches the same emissions reductions through a more detailed transition policy mix combining targeted carbon prices with green investment subsidies and regulatory measures. Both scenarios assume a baseline of no additional mitigation policies beyond those already in place. Results are reported for four regional blocks: the Euro Area, China, Oil Exporters and the Rest of the World.

**The simulations are designed to represent an orderly, credible transition in which economic agents are forward-looking and can anticipate the transition policy path, and where inflation expectations remain anchored.** Relaxing some of these assumptions allows us to explore the potential macroeconomic implications.

**The core simulations focus on near- to medium-term dynamics relevant for monetary policy, and abstract from the macroeconomic benefits of reduced physical climate damages.** These are discussed separately in Annex 1, which illustrates that avoided damages can raise output over time and offset initial transition costs. The analysis also abstracts from potential additional growth effects from faster improvements in green technologies, which could reduce transition costs further and change longer-run outcomes (Acemoglu *et al.*, 2023; Stern, 2025).[1] Moreover, any ranking of policy choices in terms of their welfare effects or efficacy in reducing emissions is strictly out of scope of this analysis. The results show that the mitigation policies tend to increase short-run inflation and put downward pressure on economic activity, and that these implications vary with policy design and expectations.

## Key messages for policymakers

**Climate mitigation policies can affect inflation and economic activity over horizons relevant for monetary policy, with macroeconomic outcomes depending on both the transition ambition and the choice of policy instruments.** As carbon prices rise and regulations and subsidies shift investment and consumption towards lower-carbon alternatives, relative prices change and some intermediate inputs (particularly fossil fuel-related energy) and production processes become more costly in the near term.

**Near-term inflation can rise as carbon prices are phased in.** The increase in headline inflation primarily reflects higher energy prices and the pass-through of higher costs in carbon-intensive sectors. Core inflation is typically less affected. Offsetting forces operate through weaker aggregate demand and (in most regions) currency appreciation that lowers import prices, helping to keep core inflation broadly flat or slightly lower. When government policies are credible, anticipated and implemented in an orderly way, the inflationary effects are generally modest at current NDC ambition.

**Output tends to fall in the short to medium term, reflecting lower returns to carbon-intensive capital.** Over the monetary policy horizon, carbon prices reduce carbon-intensive investment as fossil fuel intensive capital becomes less profitable, while green investment rises as firms substitute towards cleaner technologies. In aggregate, over the ten-year horizon, the increase in green investment is not sufficient to fully offset the decline in fossil-intensive and other investment in the simulations, reducing net aggregate investment and weighing on GDP.

**Impacts are heterogeneous across economies.** Regional impacts differ materially, reflecting differences in underlying economic structures, the implied carbon price path, and exchange rate dynamics. Inflationary pressures are larger in economies that depend more on revenues from fossil fuel production, and where there are large gaps between current transition policy and NDCs. Jurisdictions with less ambitious NDC goals experience smaller macroeconomic effects in these simulations. However, this exposes them to greater impacts if alignment with the Paris Agreement is delayed and later implemented through more abrupt and disorderly mitigation policies. For the Euro Area, headline inflation increases at peak by around 20 basis points, driven primarily by the gap between its current state and its mitigation policy ambition. For Oil Exporters, headline inflation increases up to 50 basis points, driven primarily by the depreciation of their exchange rates[2]. Exchange rate movements thus matter: currency depreciation amplifies the inflationary effects for Oil Exporters[3], while appreciation dampens them in all other regions.

**Transition policy design matters for the inflation-output profile.** A detailed policy mix that pairs carbon pricing with targeted green investment subsidies and regulatory measures can support capital accumulation in low-carbon sectors and reduce the price of some green goods over time[4]. This can partly offset carbon-price-driven cost increases, reducing the sharpness of the trade-off when

1 Stern identifies six driving forces arising from action to reduce emissions that together can generate a new growth story: 1. Lower costs, learning-by-doing, and induced innovation in the new cleaner technologies; 2. Increasing returns to scale in new technologies; 3. Greater resource efficiency across the economy; 4. Stronger system productivity, including in energy, transport, cities, land, and water; 5. Improved health, with associated higher productivity; 6. Increase in the share of investment in overall output. See Stern, 2025.

2 Exchange rates measured versus a trade-weighted basket of trading partner currencies.

3 This is driven by a reduction in global demand for fossil fuels due to carbon prices introduced across importing jurisdictions. For trade to balance after a reduction in foreign demand for fossil fuels exports, this requires a combination of their price to fall, increased sales of other exports or decreased imports. The currency adjustments through the exchange rate market ensure this happens.

4 See Table 6 in the Appendix outlining the specific green subsidies modelled under detailed policy mix.

compared with carbon pricing alone. At the same time, fiscal design also matters: larger subsidies imply higher fiscal costs where they are not funded by carbon revenues, and different approaches to revenue recycling can change the balance between supporting demand and limiting inflationary pressures.

**Expectations and credibility shape the macroeconomic path** (see e.g. Ferrari & Nispi Landi, 2024). When future government policies are fully anticipated and credible, the model produces more gradual adjustment with relatively modest inflationary effects. When government policies are not fully anticipated (or perceived as less credible), the model suggests higher and more front-loaded inflationary effects, and delayed investment adjustments. This raises the risk that second-round effects emerge if headline inflation remains elevated for an extended period. Credible, well-communicated transition policy paths help smooth adjustment.

**Monetary policy trade-offs depend on the persistence of the inflationary shock.** If higher inflation reflects primarily first-round energy and relative-price effects, 'looking through' these effects may reduce output costs but results in headline inflation remaining higher for longer, with a greater risk of second-round effects. A stronger monetary policy response returns headline inflation closer to target faster, but at the cost of weaker economic activity, illustrating the policy-relevant trade-off over the horizon considered. Indeed, part of the small observed inflationary impacts is explained by agents in the model having perfect foresight over the monetary policy response to any given climate shock where they expect the central bank to act credibly and return inflation back to target.

**Overall, the results highlight that mitigation policies can introduce persistent supply-side relative-price shocks, creating challenging trade-offs for central banks.** Any monetary policy response would require judgement about accommodating and looking through first-round effects while guarding against second-round pressures and de-anchoring of expectations. The sequencing and composition of policy packages – including decisions on revenue recycling and investment support – can materially shape the inflation and output pathways over the monetary policy horizon. Credible, well-communicated transition pathways and careful policy design can alleviate near-term macroeconomic risks.

# 1. Introduction

**The previous decade has been the warmest on record (WMO, 2025).** Higher temperatures are contributing to growing economic impacts from extreme weather events (Munich Re, 2025), with associated economic losses strongly expected to continue to increase (EEA, 2025).

**In response to the risks posed by unmitigated climate change, governments are setting targets and implementing policies to reduce greenhouse gas emissions and support a transition to net zero by mid-century (UNFCCC, 2024).** Delivering these objectives entails a broad structural transformation, including shifts in production towards lower-carbon activities and a scaling-up of investment in clean energy and other green technologies, supported by policy-driven innovation. Under the Paris Agreement, countries submit their Nationally Determined Contributions (NDCs) which outline actions to reduce greenhouse gas (GHG) emissions and adapt to the impacts of climate change. Governments have already adopted or committed to a range of climate mitigation policies to address climate change (UNFCCC, 2024) including 113 carbon pricing instruments implemented across 55 national jurisdictions as of 2025 (World Bank, 2025). Accounting for the updated NDCs submitted in advance of COP30 by 86 of 113 Parties to the Paris Agreement and covering approximately 69% of global GHG emissions, global emissions in 2035 are projected to be 12 per cent below 2019 levels (UNFCCC, 2025).[5]

**Meeting the goals outlined in countries' NDCs requires additional government policies to be implemented in the future. Central banks will need to understand the macroeconomic implications of those policies.** If recent trends in emission reductions continue, NDC commitments won't be met. This suggests governments would need to accelerate the pace of the transition and take further policy action through measures such as carbon pricing, subsidies, regulation and public investment in green sectors and technologies. While the responsibility for adopting climate change mitigation policies lies with governments, understanding their macroeconomic impacts is relevant for central banks in pursuing their core mandates of ensuring price stability. Government commitments typically extend to the medium to longer term, and transition policy actions taken or announced already increasingly have macroeconomic effects over time horizons relevant for monetary policymakers (NGFS, 2024c).

**Mitigation policies are structural policies that often ramp up over time, which means that they will need to be analysed differently than one-off economic shocks.[6]** These policies seek to address climate change primarily by reducing GHG emissions. They aim to do so by shifting energy generation, production structures and consumption patterns towards a less carbon intensive economy, and by scaling up investment in cleaner sectors. This can push down on aggregate demand and supply in the near term. At the same time, the scale of investment required to deliver the transition can act as a boost to both aggregate demand and supply, while the productivity and other benefits associated with a cleaner economy can provide a further boost over the medium to long run once the structural shifts are completed. As such, the impacts of mitigation policies differ from the standard transitory shocks typically considered in the academic literature and by policymakers. Mitigation policies nonetheless share similarities with three types of macroeconomic shocks frequently considered. First, carbon pricing acts as a cost-push shock, raising the price of fossil-fuel intensive production and consumption and transferring resources to governments via additional taxes during the transition to non-carbon energy sources.[7] Second, decreasing use and revenues from fossil fuel reserves and infrastructure (reflecting lower utilisation of fossil fuel-related fixed factors) can be thought of as a negative supply shock in the near term. Third, decreased household wealth and lower aggregate investment,

5 Note that annual emissions would need to be reduced by 35 per cent and 55 per cent in 2035 to align with the Paris Agreement 2 °C and 1.5 °C pathways, respectively (UNEP, 2025). Hence, if governments pursue more ambitious policies to meet the Paris Agreement goals, their macroeconomic impacts could be substantially larger, particularly under a 1.5 °C aligned pathway, compared to those modelled in this report.

6 While monetary policymakers devote considerable attention to longer-term structural effects such as population growth etc. the most commonly considered policy scenarios focus on temporary shocks and fluctuations. Given that climate policies, in their intent, are not transitory but implemented long-term and often with increasing stringency over time, they present a distinct case study which this report contributes to assessing.

7 A cost-push shock is a reduction in factors' revenue, which results in a lower supply of factors. Carbon pricing reduces the supply of factors generating emissions (e.g. fossil fuels). As a side effect, it can also impact the supply of other factors (e.g. labour and capital).

resulting from lower average returns on capital, can be viewed as a negative aggregate demand shock.[8]

**In aggregate, climate change mitigation policies can create inflation-output trade-offs for central banks by pushing down on output and up on inflation.** In such cases, monetary policymakers need to balance policy tightening to combat near-term inflationary pressure with adjusting the degree of restrictiveness to account for the negative effects on output. In the longer-term, the NGFS scenarios (2023) and some of the more recent empirical findings (e.g. Bilal & Känzig, 2026) suggest that the near-term economic costs of mitigation policies are outweighed by the expected benefits of the green transition.[9] Actions to reduce emissions such as green investment and innovation could also contribute to stronger long-run economic growth (Acemoglu *et al.*, 2023; Stern, 2025). In the short to medium term, since they act as implicit constraints on GHG emissions associated with various production and consumption processes across the economy, they can lead to increased prices and reduced output growth. Central banks typically look through temporary increases in headline inflation due to supply-side and one-off cost-push shocks.[10] However, persistent increases in inflation, for example due to phased-in carbon pricing passing through to higher energy prices, may require a monetary policy response to prevent second-round effects and a potential de-anchoring of inflation expectations.[11] In this context, there can be a trade-off between the degree to which monetary policy acts to contain the increase in headline inflation or to cushion the fall in output.

**To understand potential monetary policy trade-offs arising from different climate mitigation policies, this report harnesses the IMF's Global Macroeconomic Model for the Energy Transition (GMMET).** GMMET is a large-scale structural New-Keynesian dynamic general equilibrium model with a granular representation of key GHG-emitting sectors. This sectoral detail allows the model to capture heterogeneous production technologies, energy use, and substitution possibilities across the economy, making it well-suited to assess macroeconomic impacts of mitigation policies. The broad set of nominal and real rigidities incorporated in GMMET also make it a good tool for analysing monetary policy responses and provides a distinct advantage over other types of models (NGFS, 2024a). This analysis focuses on the economic effects of mitigation policies to achieve NDCs at short- to medium-term (1 to 10 years) horizons. Potential 'mitigated damages' that could be achieved if NDC commitments are met are discussed separately (see Annex 1). The analysis considers two sets of policy scenarios: one where NDC-implied emission reduction targets are achieved solely through region-specific carbon pricing, and another in which the same emission reductions are achieved via more granular, region-specific policy mixes (including sectoral subsidies and regulation).

**Overall, the analysis finds that under the standard assumptions embedded in the GMMET model, a gradual and anticipated implementation of NDC-aligned mitigation policies has relatively limited inflationary impacts. There are, though, important heterogeneities based on region and transition policy mix which will require careful management by monetary policymakers.** In the scenario where NDCs are delivered solely through rises in carbon prices, headline inflation increases at peak 20 basis points in the Euro Area and up to 50 basis points in Oil Exporters during the five-year period over which the carbon policies are phased in. Inflationary impacts are exacerbated for Oil Exporters as their currencies depreciate due to the reduction in their current and future oil and gas export revenues. In other regions, reduced demand for imported fossil fuels leads to currency appreciations, offsetting some of the inflationary pressures.

**The results also show that the mix of mitigation policies matters for macroeconomic outcomes.** For example, when

8 Part of the impact of mitigation policies looks like an aggregate demand shock as households decrease consumption and firms decrease investment.

9 Importantly, this analysis focuses on the short- to medium-term and abstracts from physical damages of climate change in most simulations (see Annex 1 on the effects of mitigated physical damages).

10 See the broad literature on monetary policy response to cost-push, supply- and demand-side shocks (e.g. Smets & Wouters, 2003; 2007; Blanchard & Gali, 2007; Bandera *et al.*, 2022; Giannone & Primiceri, 2024).

11 Recent studies find that inflation expectations may be particularly influenced by energy prices (e.g. Dietrich, 2024; D'Acunto *et al.*, 2024; Patzelt & Reis, 2025).

carbon pricing is combined with revenue recycling targeted at subsidising renewable energy[12] investment, some of the increases in average energy prices due to carbon pricing are offset by a fall in the price of non-fossil fuel intensive energy output reducing short-term inflationary pressure though at a cost of lower consumption. If carbon price revenues were instead redistributed as a broad-based investment subsidy to all sectors of the economy, peak inflationary effects are higher, reflecting the greater increase in aggregate demand from higher real investment (see Box 1).[13] The modelling also illustrates how expectations and policy credibility matter for macroeconomic outcomes. If policy is not credible, the short-term inflationary effects can be higher due to aggregate demand impacts (see Box 2).

**The findings highlight that climate mitigation policies can create inflation-output trade-offs for central banks.** The introduction of carbon prices can generate impacts on both inflation and output that persist over the policy-relevant time horizon. The results show an increase in headline inflation (primarily reflecting higher energy prices). At the same time, core inflation remains flat or slightly decreases in all regions and economic growth decreases, as total investments decline, given that the increase in green investment is not sufficient to offset the drop in fossil-intense investment over the time horizon considered here.[14] During the phase-in of carbon prices, monetary policymakers will therefore need to consider both the inflationary pressures of carbon prices and their contractionary effects on output.

**The modelling of the carbon pricing scenario relies on a range of assumptions.** First, agents have perfect foresight and climate policies are fully credible and anticipated. Second, carbon tax revenues are distributed as lump-sum transfers to households. Third, monetary policymakers look through first-round effects on headline inflation, balancing inflation and output stabilisation in their response. Fourth, inflation expectations remain anchored. Fifth, the model does not account for fluctuations in carbon-intensive energy prices driven by exogenous shocks[15], and assumes that transition-related effects dominate. The main results also do not account for the impact of reduction in physical damages related to mitigation policies. Further, the model considers five country aggregations which necessarily hide regional economic and government policy heterogeneity. It also assumes that all regions have flexible exchange rates and a degree of wage flexibility, though Box 2 on the role of expectations provides some insights in the scenario where the exchange rate adjusts more slowly.

**The analysis focuses on the likely near-to medium term effects on GDP and inflation and their monetary policy implications. It does not undertake a welfare analysis of different climate policies nor an assessment of the efficacy of different government policies in reducing emissions.** In the model, carbon prices are the key policy driving emission reductions, in line with literature which finds carbon pricing to be the most efficient government policy approach for tackling climate change (see e.g. Parry *et al.*, 2022; Chateau *et al.,* 2022; van den Bergh & Botzen, 2024). Although our scenarios focus on redistributing carbon tax revenues to consumers, revenue recycling to green goods and investment subsidies leads in general to less of a fall in output and reduced inflationary pressures over the period we are looking at. This is a general feature of fiscal modelling, rather than a climate-specific conclusion. Further, the analysis does not undertake a fiscal assessment of any government policies, an important dimension as higher subsidies imply higher fiscal costs where they are not funded by increased tax revenues.

**Future costs of green technology are also a key point of uncertainty.** While simulations assume trend technology improvements, they do not allow for faster technological improvements if adoption of green technologies increases. This assumption is reasonable given the short to medium run focus of the analysis, and given the relatively sudden

12 Costs of renewable energy generation are projected to fall in line with trend technology improvements regardless of subsidies, but by accelerating the deployment of renewable power, subsidies shorten the horizon at which renewables push down on average energy prices.

13 Targeting only green capital limits the scale of the subsidy since it is a small share of overall capital. A broad-based subsidy which utilises all carbon tax revenue therefore produces a greater injection of capital into the economy.

14 If monetary policy was perfectly strict, core inflation would remain at target. Where core inflation falls this is primarily due to aggregate demand impacts, not because of credibility. See also Box 2 for a discussion on the role of agents' expectations and policy credibility in moderating the inflationary effects observed.

15 As for example energy price fluctuations associated with increased geopolitical uncertainty, including gas prices in 2022 and oil and gas prices in 2026.

deployment of battery storage at scale[16], we could not consider the implications of this technology in this particular modelling exercise. Nonetheless, cheaper green technology costs would reduce costs of mitigation policies, and in the long run green innovation could drive economic growth (Acemoglu *et al.*, 2023) alongside other driving forces arising from emission reduction actions (Stern, 2025).

**These results add to previous findings on impacts of carbon prices and green subsidies on inflation.** Bilal and Stock (2026) analyse the literature on the macroeconomic consequences of climate mitigation policies. Several empirical studies show that carbon prices typically generate upward pressures on headline inflation, but less on core inflation (IMF, 2022; Brand *et al.*, 2023; Breckenfelder *et al.*, 2023; Coenen *et al.*, 2024; Ferdinandusse, Kuik and Priftis, 2024; Känzig, 2023; Känzig & Konradt, 2023; McKibbin *et al.*, 2021), with the magnitude of effects depending on factors such as implementation pace and revenue allocation. A few studies, however, do not find significant inflationary effects (Konradt & Weder di Mauro, 2023; Kapfhammer, 2023). For studies that find deflationary effects, the modelling of expectations appears to be important with households anticipating further increases of carbon prices, leading to reduced current demand (Ferrari & Nispi Landi, 2024). Subsidies for green energy typically create deflationary pressures (Jondeau *et al.*, 2022; Bistline *et al.*, 2023; Airaudo *et al.*, 2023; Voigts & Paret, 2024; Priftis & Schoenle, 2025).

**This analysis adds to existing NGFS work by simulating detailed mitigation policy scenarios and their monetary policy implications.** An earlier NGFS report (2024c) summarises the literature on how climate change and mitigation policies affect macroeconomic outcomes and monetary policy, highlighting that these transition policies can create inflation-output trade-offs requiring further investigation. This analysis makes several distinctive contributions. It analyses mitigation policies in a global model, it relies on NDCs to define region-specific emission pathways and it assesses granular government policy mixes – including sectoral carbon prices and subsidies – rather than individual policies in isolation. It complements the NGFS short-term scenarios (NGFS, 2025) by assessing the effects of a central case transition scenario and comparing different mitigation policy mixes. It also adds to the NGFS occasional paper by Burgert *et al.* (2025), who compare the effects of energy price increases across different DSGE-models. Lastly, this report provides analytical groundwork for the seperate NGFS publication on climate implications for monetary policy strategy, including considerations across different monetary policy regimes beyond inflation-targeting (NGFS, 2026).

16 See Rangelova & Jones (2025).

# 2. Analytical Framework

*This chapter provides an overview of the analytical framework. Section 2.1. introduces GMMET, a model that leverages the structural core of the IMF's workhorse Global Integrated Monetary and Fiscal Model (GIMF) to create a macroeconomic model suitable for energy policy analysis. GMMET is designed to assess the macroeconomic impacts of the energy transition and incorporates detailed modelling of energy production, trade and emissions across sectors. It allows the analysis of the effects of different mitigation policies, including carbon prices and subsidies. Section 2.2. outlines the baseline and transition scenarios analysed in this report. While the baseline assumes current government policies and builds on historic emission data, the two transition scenarios are aligned with emission pathways outlined in countries' NDCs. Both the baseline and the scenarios abstract from physical damages arising from climate change. The first scenario explores the impact of reaching NDC-aligned emission targets through carbon prices alone, while the second considers a more detailed mitigation policy mix based on countries' announced plans that also includes subsidies and regulation.*

## 2.1 Model and Calibration

**GMMET is a global large-scale non-linear structural New-Keynesian dynamic general equilibrium model, featuring five regional blocks.** These types of models are traditionally used for the quantitative short- and medium-term analysis of monetary and fiscal policy and a variety of macroeconomic shocks. GMMET builds on the IMF's workhorse Global Integrated Monetary and Fiscal model (GIMF, see Laxton *et al.*, 2010). In this model, households and firms are forward-looking and choose consumption, labour supply, asset holdings, and investment optimally, considering their preferences and expectations about the future. Nominal and real frictions as well as the explicit modelling of expectations allow the analysis of cyclical fluctuations and stabilization policies. The model features the following regional blocks: the US, Euro Area, China, an aggregate block of Oil Exporters and an aggregate block of remaining countries. The Annex provides more details on the composition of regional blocks.

**GMMET significantly extends GIMF to capture various aspects of energy production, trade, and use by various sectors, and their implications for emissions.** In the following, we summarize key aspects of the model and refer the reader to Carton *et al.* (2023) for a detailed model description. Carton *et al.* (2026) provides details on more recent model features, including energy-efficiency capital and the heating sector.

- Fossil fuel (oil, fossil gas and coal) mining requires three factors (labour, physical capital and endowment). Their initial shares match revenue shares and their short- and long-run adjustment to fossil fuel price changes are consistent with empirically estimated supply elasticities. Fossil fuels are internationally traded.
- Electricity is generated from five different technologies differing in their cost structure and emission intensity: Coal, fossil gas, nuclear power, hydroelectric power, and renewables. Fossil fuel costs are determined based on the medium to long term demand and supply dynamics, and do not account for price volatility from exogenous shocks such as due to geopolitical developments.
- To capture the intermittency of renewable energy generation (driven by fluctuations in the intensity of sunshine and wind), the model assumes that this technology must be paired with a flexible backup (gas generation).[17] The required backup capacity and generation results from a cost-minimization problem that accounts for the variable and fixed costs of both technologies, as well as the distribution of weather regimes.
- The model features a dedicated transportation sector that distinguishes between internal combustion engine cars burning fossil fuel and electric vehicles running on electricity. The sector has stock-flow accounting of fleets and newly purchased vehicles. It also features an explicit role for charging and fuelling stations, capturing network externalities between electric vehicle adoption and the deployment of charging stations.
- GHG emissions unrelated to burning fossil fuels are tracked, and the possibility to abate them is accounted for by sector-specific emission abatement technologies. Their calibration is based on sectoral estimates of marginal abatement costs.

17 Given the relatively sudden deployment of battery storage at scale, we could not consider the implications of this technology in this particular modelling exercise. However, future iterations will look to consider the consequences of low-cost storage technology on the macroeconomic effects of climate mitigation policies.

- In both the tradable goods and energy-intensive tradable goods sectors, sector specific energy-efficiency capital can be deployed to substitute for fossil fuels as input to the production process.
- The heating sector provides heating services to households and to the non-tradable goods sector. Heating can be produced from fossil gas and electricity; each combined with fuel-specific capital. Insulation capital can be substituted for heating services.

**The model features a detailed fiscal sector with a variety of fiscal revenues and spending instruments.** GMMET allows for a suite of emission reduction policies including carbon prices, subsidies to low-emission technologies, such as, e.g., renewables electricity capital, electric vehicles (EVs), energy-efficiency capital or insulation, or regulatory measures, which are typically implemented so that any price increase passed on only reflects the increased cost of production.[18] As a general assumption in the model, government debt is held constant relative to GDP throughout the modelled scenarios.

**Monetary policy is modelled by a standard policy rule, where policy responds to deviations of core inflation from target and the neutral rate to stabilize inflation.** The inclusion of the neutral real rate in the central bank policy setting rule ensures the central bank responds not only to inflation but also to underlying economic conditions, and ensures the model is stable to structural changes that alter the long run real rate of return.[19] The neutral rate used by the central bank is an estimate given by the HP filtered real interest rate.[20] Monetary policy features interest rate persistence and the inflation target is a weighted average of current and next period core inflation. The alternate monetary policy rule, used to illustrate monetary policy trade-offs, is detailed in the scenario description in Section 2.2 below.

## 2.2 Scenario Description

**We analyse the macroeconomic implications of the green transition by comparing a baseline scenario with two transition scenarios aligned with governments' NDC emission reduction targets.[21]** The baseline assumes that historical emission trends over the past ten years continue. This can be thought of as no additional government policies being introduced to speed up the reduction of GHG emissions beyond the emission reduction trends of mitigation policies already effective at the start of the simulation (2025).[22] The two transition scenarios both assume that governments meet their NDC targets for reducing national GHG emissions, but with different combinations of government policy instruments used to reach those targets. In addition, the core analysis abstracts from physical damages arising from climate change, both in the baseline and the scenarios modelled, which are considered separately (see Annex 1).

**Emission pathways for the baseline are constructed from historical emission data over the past 10 years, while for the transition scenarios they are derived from NDC pledges.** For the baseline, emission pathways are derived by linear extrapolation from historical emission trends over the past ten years, drawing on available data for each country or region included in the analysis. Where necessary, adjustments were made to account for data gaps or region-specific historic events (see Annex for details). For the transition scenarios, annual emission reductions are obtained through linear extrapolation of NDC pledges from the base year to interim and net zero targets, as set out in countries' or regions' NDC submissions to the United Nations Framework Convention on Climate Change (UNFCCC), as of May 2025. As a granular approach is not feasible for all 194 countries within the context of this analysis, the blocks of Oil Exporters and Rest of the World are represented by emission pathways based on the five highest-emitting countries in each region, which serve as proxies for NDC implementation at the regional level (see Annex for details). Results in section 3 focus on analysing macroeconomic impacts and monetary policy

18 This is done *via* revenue-neutral tax-subsidy combinations where one or more inputs of a sector are taxed, and the revenues used to subsidize the remaining inputs of that sector. Shadow prices of carbon or similar would be passed on to users and are therefore not used for regulation.

19 Under structural changes the neutral real rate can change (as happens in scenarios modelled here). In steady state, the interest rate the central bank sets needs to be consistent with the neutral real rate, so the neutral real rate needs to enter the interest rate setting equation.

20 This contrasts with New-Keynesian models that often interpret the neutral rate as the interest rate absent nominal rigidities (i.e., natural rate). The inclusion of the HP filter estimate of the neutral rate reflects potential gradual adjustment by the central bank to changes in the neutral rate.

21 This analysis updates and extends on the results of the International Monetary Fund (2022), notably by introducing a new regional block of Oil exporting countries, focus on a more central transition scenario aligned with NDCs, and deepening the assessment of monetary policy trade-offs.

22 For more details please refer to Annex 2.2 (a).

implications for modelled regions that introduce NDC-aligned mitigation policies. For the US, no emission reduction targets are assumed compared to the baseline, consistent with their January 2025 submission of notice to withdraw from the Paris agreement.[23]

**Under the transition scenarios, NDC-aligned emission reductions are achieved through either (i) carbon prices alone or (ii) a combination of policy instruments, namely price-based policies, subsidies, and regulation.** The first scenario is a stylized case that assumes uniform carbon prices across all sectors within a region as required to meet NDC targets. Carbon prices are effectively endogenous to meet 2035 NDC targets. A NDC pathway is not targeted, rather only 2035 NDC pledges are targeted. Carbon prices are phased-in over 5 years and then held constant. A simplifying assumption is made that revenues from the carbon prices are recycled via lump-sum transfers to households, to isolate the macroeconomic effects of carbon prices without further assuming how the government might use the revenues. An alternative specification of this scenario, where the government uses the revenues for a broad sector-agnostic investment subsidy is also modelled, to illustrate how the macroeconomic effects would differ (see Box 1). The second scenario also meets NDC targets, but through a more detailed policy mix drawing on announced government plans in NDC submissions or closely associated official government documents such as the EU's Fit for 55 programme. Where no sector-specific emission targets are specified in NDC submissions, relative sectoral contributions to country-level emission reductions are determined based on each sector's current share of GHG emissions. For aggregate regions, i.e. Oil Exporters and the Rest of the World block, the same proxy countries as for the computation of the emission pathways are used. For each proxy country, sector-specific mitigation policy mixes are identified and aggregated with a weighting factor based on their share of the region's overall GHG emissions. In cases where policy types are not sufficiently specified, existing policy instruments currently in use were assumed to remain dominant in the relevant sector or country.

**These scenarios therefore reflect the current level of ambition in regional NDCs, and not the increase in mitigation policy ambition required to meet the goals of the Paris Agreement.** Jurisdictions with less ambitious NDC goals therefore see smaller increases in carbon prices (see Table 1) and in turn reduced macroeconomic impacts, but can be exposed to greater impacts and trade-offs in the future if they then implement policies seeking alignment with the Paris Agreement in a more abrupt way.

**To illustrate the trade-off faced by central banks, we run each scenario under two assumptions of the central bank's monetary policy response.** The first case assumes the central bank looks through first-round impacts of climate policies on energy prices.[24] The second case assumes the central bank responds to changes in headline inflation including those coming through energy prices. We provide technical discussion of the implementation in the Annex.

Table 1 **Scenario Description by Region**

| Region | Emission reduction by 2035 (relative to baseline, implied by NDC pledges) | Scenario 1: Regional carbon prices[25] (phased in over five years, revenue recycling *via* lump-sum transfers) | Scenario 2: Detailed policy mixes (informed by regional plans) |
|---|---|---|---|
| China | -15% | $30 | Mainly phasing out of coal subsidies with minor carbon price on remaining sectors. |
| Euro Area | -30% | $240 | Mainly carbon pricing (ETS); revenue recycling of 60% into renewable capital. Some regulation to shift preferences to EVs. |
| Oil Exporters | -19% | $55 | Mainly electricity sector regulation, with shadow price on coal and gas, EV subsidies and price on non-fossil fuel emissions. Minor carbon price on remaining sectors. |
| Rest of the World | -26% | $110 | General carbon price with revenue recycling of 40% subsidy on renewable capital and EV subsidy. |

23 See White House (2025).

24 This assumes that the central bank targets core inflation which excludes energy prices and ignores measures that directly affect consumer prices, such as EV subsidies.

25 Carbon prices are set in USD and by ton of carbon dioxide equivalent ($CO_2e$).

# 3. Findings

*This chapter presents the main findings. Section 3.1. shows the results from implementing economy-wide carbon prices to achieve NDC targets, with revenue rebated to households via lump sum transfers and central banks looking through first-round effects on energy prices. The findings under this scenario suggest that carbon prices can affect inflation and output over horizons relevant for monetary policy. The magnitude of these effects depends on regional economic structures and mitigation policy ambition. In particular, currency depreciation exacerbates inflationary impacts for Oil Exporters. In other regions, currency appreciation offsets some inflationary pressures from higher energy prices. By comparing these macroeconomic outcomes under the 'looking through' approach with standard headline inflation targeting, the analysis illustrates the inflation-output trade-offs that climate mitigation policies may generate. Section 3.2. compares these results with a scenario that achieves NDCs through a detailed policy mix more closely aligned with announced government policies. In this scenario, negative GDP effects are more contained, while inflation impacts vary by regional mitigation policy mix. Similar to the carbon price scenario, the effects persist over the phase-in period of additional policies, and can create trade-offs for central banks, though they are somewhat less acute for most regions. The results presented in this section do not incorporate economic effects from damages avoided due to extra climate policy action.*

## 3.1 Macroeconomic Effects of an NDC-aligned Carbon Pricing Scenario

**Carbon pricing puts upward pressure on headline inflation in the short- to medium term, with the magnitude varying across regions due to differences in carbon prices and fossil fuel intensity.** Under the starting assumption of central banks 'looking through' the first-round effects of energy-related inflationary pressures, Oil Exporters face the sharpest increases in both headline and core inflation during the phase-in of carbon prices (the first five years), reflecting the fossil-fuel-dominant nature of their economies. With a global decrease in fossil fuel demand and declining fossil fuel export revenues, their currencies depreciate, which raises import prices and adds to the inflationary effect of carbon prices (see Figure 3). The Euro Area experiences an increase in headline inflation as shown in Figure 1, reflecting relatively high carbon prices as implied by its ambitious NDC goals.

**Concurrently, aggregate demand declines and exchange rate appreciation creates deflationary pressures in most regions, counteracting the direct inflationary impacts of carbon prices.** Aggregate demand decreases primarily due to declines in aggregate investment, discussed in detail below. Figure 4 shows that inflationary pressures are further moderated by lower (albeit still positive) wage growth resulting from weaker labour demand and falling fossil fuel producer prices (excluding the carbon price component). Real wages also continue to increase, at a lower rate, in all regions with the exception of Oil Exporters which experience a brief period of negative real wage growth (see Figure 5).

**Changes in relative prices also have macro impacts through household consumption channels, albeit through a secondary role.** Climate policies are intended to change the production structure of the economy and therefore act most directly on the firm side, changing sectoral allocations and investment decisions. Households respond to changes in wages, incomes and wealth that result from the climate policies implemented. Consumption rises in the near term in most regions, except in Oil Exporters (see Figure 8), as households undertake less saving due to lower real rates. The consumption subsidy from recycling carbon tax revenues as lump sum transfers is offset by lower dividends households receive from firms. This is because companies pay higher carbon prices which means they pay lower dividends. If firms didn't respond to relative price changes from carbon pricing and they were not passed on, there would be an economic impact from the collection of carbon taxes and their redistribution. Overall, it is the changes in relative prices due to carbon prices that have economic impacts.

**Currency appreciation in the Euro Area, China, and the Rest of the World block reduces import prices; this partially offsets inflationary pressure** (see Figure 3). Most exchange rate adjustment occurs in the first period after implementation of carbon prices, reflecting agents' anticipation of the climate policy path and its macro effects. As a result, core inflation remains largely unaffected or declines slightly, except for Oil Exporters where core inflation increases due to higher import prices resulting from the above-mentioned currency depreciation.

Figure 1 **Headline inflation**

*(percentage points)*

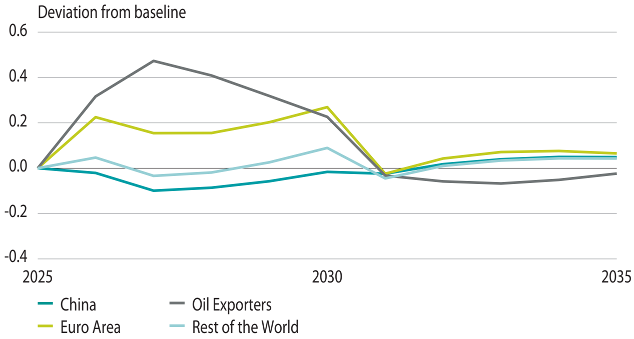



Figure 2 **Core inflation**

*(percentage points)*

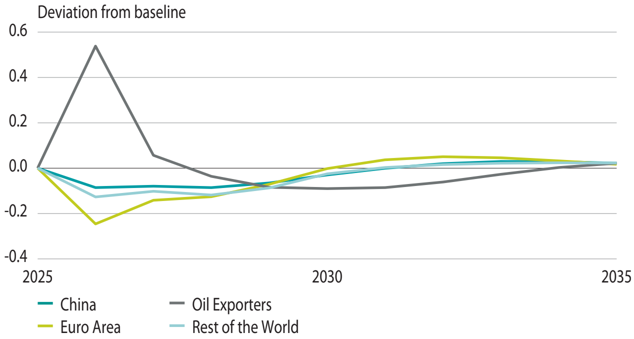



Figure 3 **Trade weighted exchange rate**

*(%)*

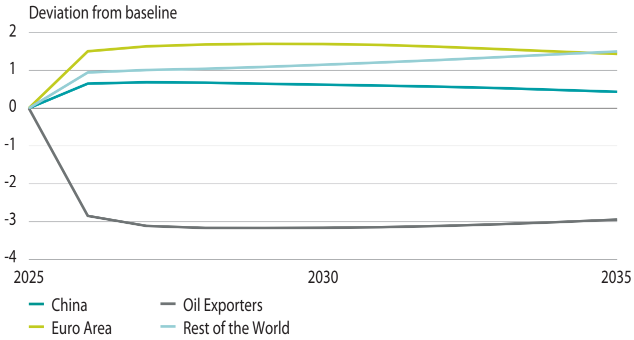



Figure 4 **Nominal wage growth**

*(%)*

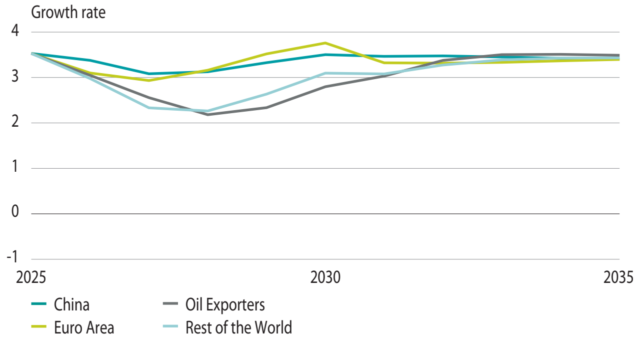
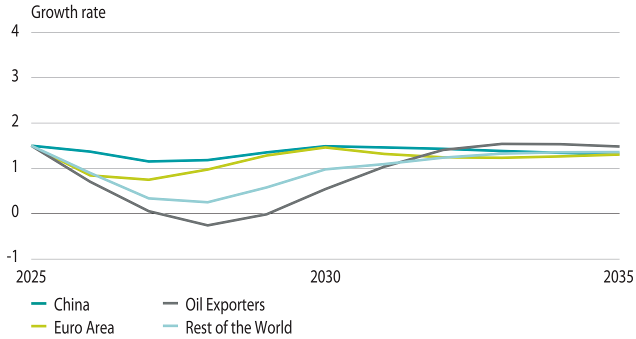



Figure 5 **Real wage growth**

*(%)*




**Carbon prices reduce aggregate investment in the short to medium term for all regions, despite increasing clean technology investment.**[26] Across the whole economy, capital and energy are complements in production. Higher energy prices therefore reduce the return on capital and its overall demand. Notably, two counteracting effects are driving this aggregate outcome. On the one hand, higher energy prices discourage investment in the "high-emitting" capital stock used for extracting or utilizing fossil fuels, as returns on related investments are reduced. On the other hand, substitution effects increase investment in "green" capital stock used to produce renewable energy or increase energy efficiency in production. As shown in Figure 6, increases in clean investment are insufficient to offset the decline in investment in high-emitting capital stock. Consequently, aggregate investment declines, though the extent varies by region. Specifically, the Euro Area and China experience smaller investment contractions than Oil Exporters and the Rest of the World. This reflects the EU's

26 While the green transition requires substantive investment, after accounting for the general equilibrium effects and cheaper abatement options, this may not fully offset declines in other sectors. For example, in the Euro Area, modelled increases in green and reductions in carbon-intense investments offset, and it is other sectors that drive the net decrease.

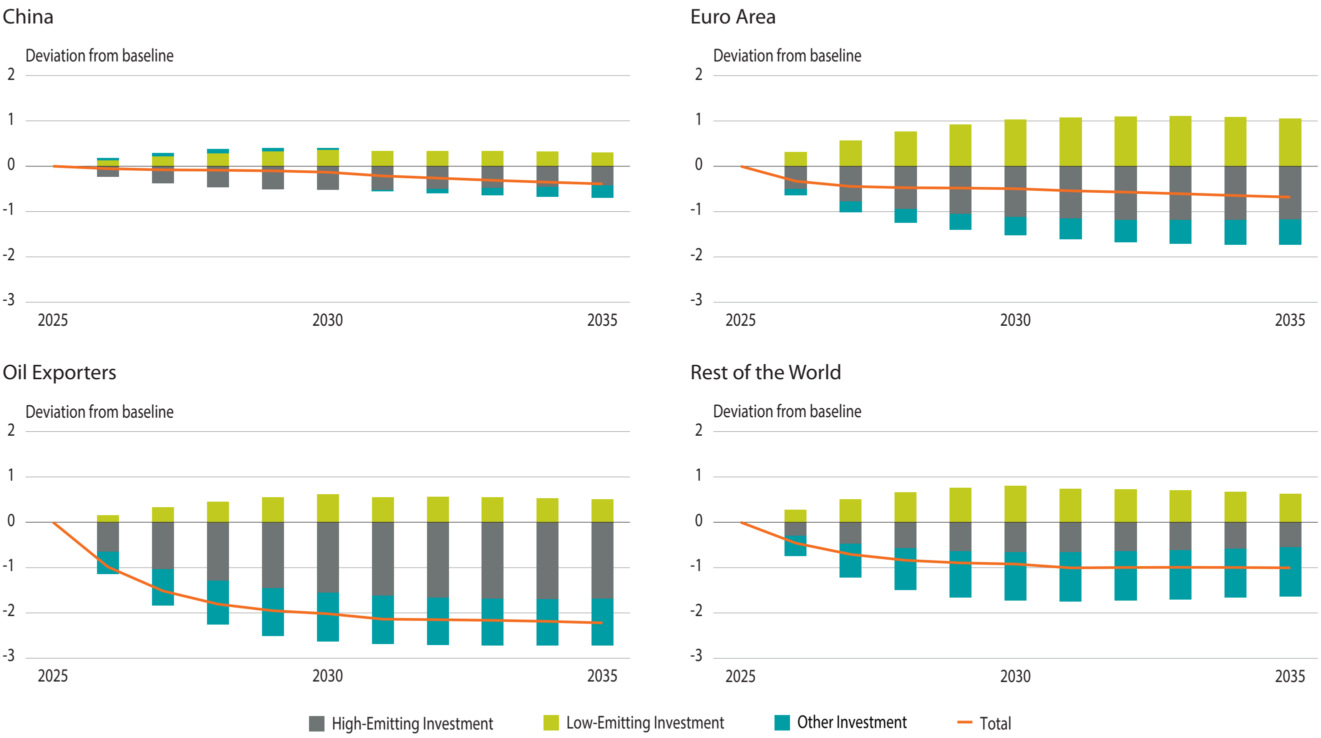
larger green investment increase and China's smaller drop in fossil-intense investment, compared to a substantial drop in fossil-intense investment for Oil Exporters and the Rest of the world, driven in part by reduction in global oil and gas demand.

**The decline in investment in this scenario is driven by four key assumptions which if modified, could suggest a smaller decline.** First, revenues from carbon prices are rebated as lump-sum transfers to households and are not channelled into green investments (see Section 3.2 and Box 1 for alternate scenarios regarding subsidies and revenue recycling). How revenues from carbon taxes are used is a matter for governments, whose choices balance a range of objectives beyond economic efficiency, such as redistributive and public support considerations (see e.g. Carattini *et al.*, 2017). Second, GMMET abstracts from increases in clean tech productivity that may be driven by additional adoption of these technologies. Third, GMMET also abstracts from long-term productivity gains of mitigating physical damages (see Annex 1 for an analysis of mitigated damages). Fourth, we model simultaneous action across the four different country blocks outlined earlier. As such, global GDP is lower; this decreases export demand for each region, and thereby investment.[27] Over the longer term, productivity gains from green innovation, alongside related driving forces from emission mitigation actions such as greater resource efficiency, improved health associated with higher productivity, and increase in the share of investment in overall output could boost global economic growth (see e.g. Acemoglu *et al.*, 2023; Stern, 2025).

**Notably, the model assumes inflation expectations remain anchored and real wages can adjust in a sluggish manner, in line with estimates of how quickly wages adjust when economic conditions change.** Wage stickiness is obtained via adjustment costs calibrated in line with the literature.[28] While not modelled explicitly here, a de-anchoring of inflation expectations, or workers resisting slower growth in their real wages would result in stronger inflationary pressures.[29] The modelling of expectations also matters. If agents do not expect future carbon price increases, core and headline inflation can be higher in the short term, as investment is initially less adversely impacted, and exchange rates adjust more gradually (see Box 2).

Figure 6 **Real Investment per region**

*(% of GDP)*




27 Carton *et al.* (2026), using the same GMMET model harnessed here, find a positive aggregate investment response in the EU when the EU acts alone.

28 It is worth noting that in all scenarios and all periods and regions, nominal wage growth remains positive (assuming a baseline of 2% inflation and 1.5% productivity).

29 Steady state nominal wage growth is 3.5% in GMMET. Also see Figure 17: Real wages under CP and DP per region.

**Carbon prices reduce output with effects that persist over the monetary policy horizon.** As fossil fuel reserves extracted in the mining sector are an economic endowment, a policy that limits the use of fossil fuels, reduces the extent to which economic rents from this endowment can be exploited. In short, the mitigation policy incentivizes a shift to renewable energy endowments that is insufficient to counteract the hit to productivity associated with the shift away from fossil fuels, thus lowering overall productivity in the short to medium term. The mechanism behind this is that the shift effectively makes energy, a complement to other factors in production, scarcer over the initial period of the transition. Eventually, beyond the horizon of our analysis, it may be possible for the shift to non-fossil energy sources alongside improvements in energy efficiency to offset the phase-out of fossil energy (see e.g. IEA, 2025). In addition, the model does not capture increased technological progress in green technologies from increased adoption and the additional cost declines in green technologies that would result. Cheaper green technology costs would reduce costs of mitigation policies. Lower energy utilisation and aggregate capital stocks therefore contribute to slower growth over the horizon considered for our analysis.[30]

**Results show that Oil Exporters, for which fossil fuel mining contributes significantly to overall output and external revenue, experience the largest output losses due to declines in aggregate investment, and lower exports.** In contrast, China experiences only a small decline in output, reflecting a smaller gap between its baseline scenario and additional mitigation policies to meet its NDC and hence smaller carbon price increase and limited decrease in aggregate investment.[31] Figure 8 shows that household consumption declines in the longer term due to lower real wages and incomes. However, it temporarily increases in the short to medium term due to lower real interest rates that discourage saving.

Figure 7 **Real GDP**

*(%)*

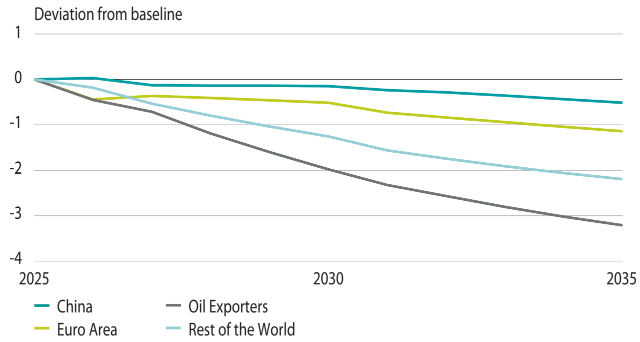



Figure 8 **Real consumption**

*(%)*

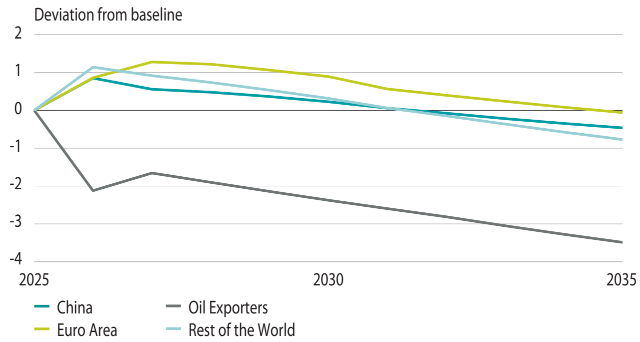
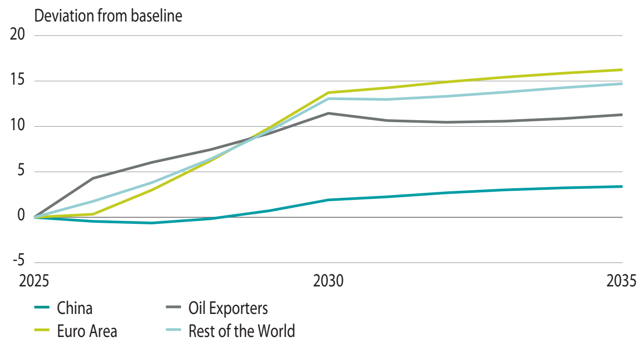



Figure 9 **Price of electricty**

*(%)*




30 Carbon prices, in the absence of other tax reduction or subsidies, raise fiscal distortions and thereby lower GDP.

31 The comparatively benign deviation between China's baseline and NDC scenarios is due to a combination of two factors: First, NDCs and hence the baseline were computed on the basis of carbon intensity rather than absolute emissions in accordance with China's 2021 submission to the UNFCCC rather than its updated NDC submitted in November 2025. Second, China has made fast progress towards its NDCs set in 2021 over the past years which causes a continued decline in its carbon intensity in the future in the baseline scenario.

**Carbon prices lead to a near- to medium-term decline in the neutral rate of interest, as shown in Figure 10.**[32] Carbon prices reduce the average return on capital due to the average complementarity between capital and energy.[33] Since the neutral rate enters the central bank's monetary policy rule, its decline contributes to lower nominal interest rates, as shown in Figure 11. Households anticipate future income reductions and lower wealth, reducing their consumption. However, lower real interest rates cause households to shift consumption forward, raising near-term consumption (see Figure 8). As such, the decline in the neutral rate helps partially offset the fall in investment and balances aggregate supply and demand. Box 1 discusses in more detail how assumptions on revenue recycling affect neutral rates. The decrease in the neutral rate is smaller if revenues from carbon pricing were used to fund green investment subsidies, instead of being transferred to households. Box 1 also extends the analysis to the longer run (i.e. beyond the time horizon of 2035 analysed in this chapter).

Figure 10 **Neutral real rate**

*(percentage points)*

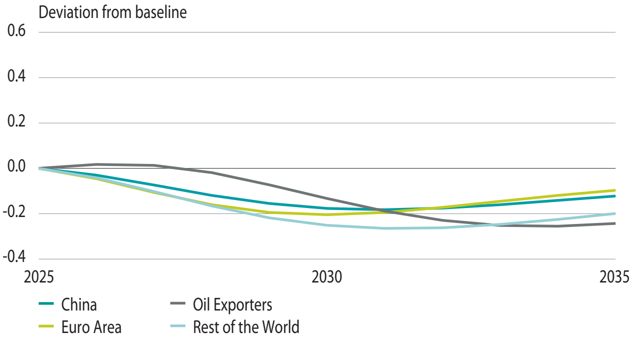
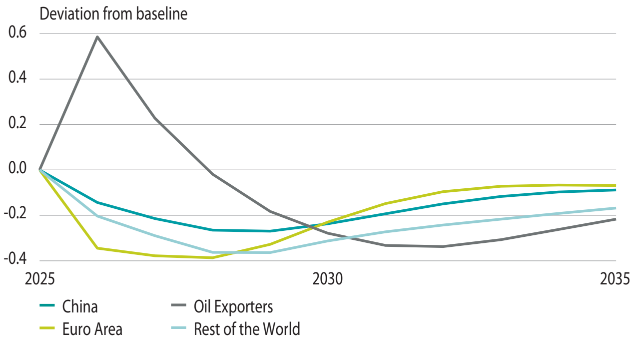



Figure 11 **Nominal interest rate**

*(percentage points)*




## Box 1

### Neutral rate and subsidies

*In the near to medium term, simulation results indicate a decrease in the neutral rate under the carbon pricing scenario, reflecting reduced return on capital. This box analyses how the use of carbon pricing revenues affects neutral rate impacts. It shows that in the detailed policy mix scenario, where part of the revenue is used to fund targeted green investment subsidies, the fall in the neutral rate is partially mitigated. Further, in an illustrative scenario, in which the full revenue is used to fund broad investment subsidies, the neutral rate increases. The box also extends the analysis beyond the near to medium term covered in the main sections of the report. In the long run, neutral rates rise relative to the baseline, reflecting the higher capital intensity of the decarbonised economy.*

**The impact of climate mitigation policies on the neutral rate is widely debated among researchers.** Initially, mitigation policies may lead to reduced average return on capital and a decline on aggregate investment, leading to downward pressure on neutral rates. In the longer-run, many expect them to put upward pressure on neutral rates, reflecting the large-scale investments required for the transition, possible increases in public debt to finance transition efforts, and expected increases in the productivity of green technologies, if they are widely adopted (see NGFS, 2026 for a detailed overview).

.../...

32 The neutral rate balances the longer-term supply and demand of capital. The neutral rate is described at the end of section 2.1.

33 Similarly, IMF (2023) finds neutral rates broadly decrease during the phase in of the carbon price.

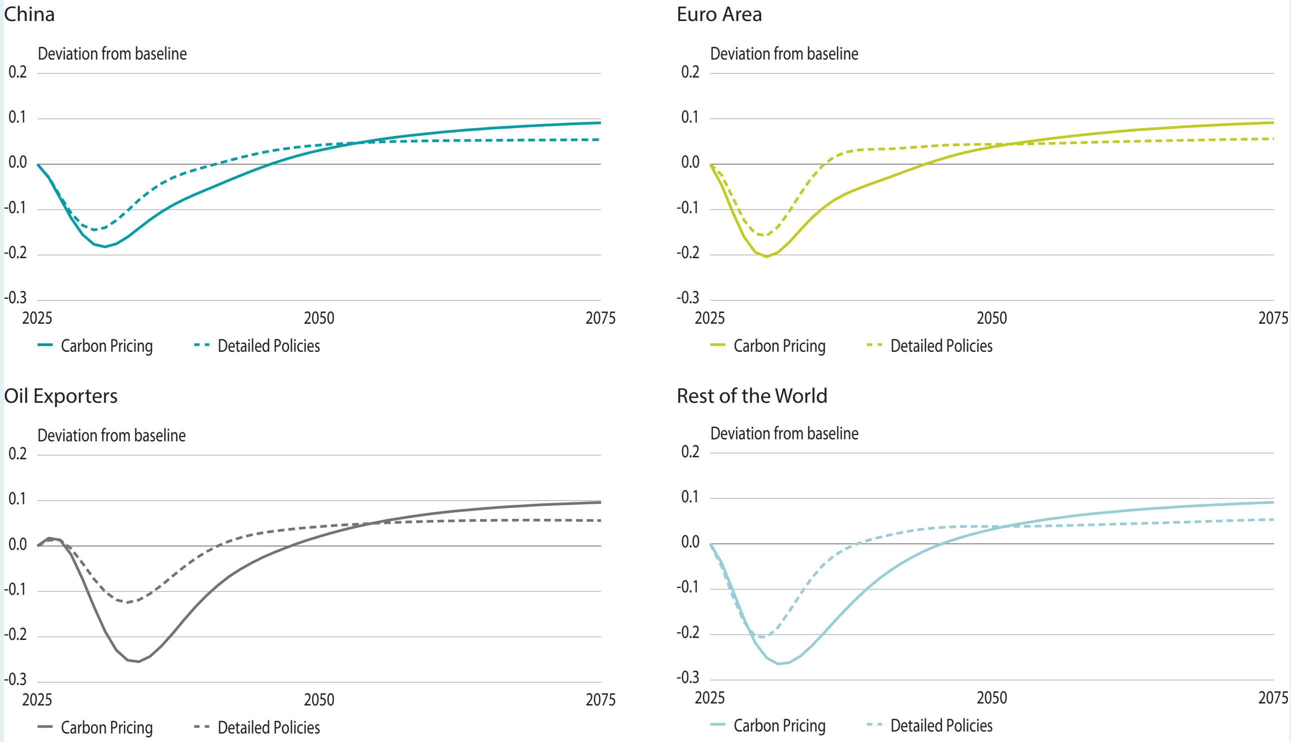
**Both the carbon pricing and detailed policy mix scenarios lead to an initial decline in the neutral rate** (see Figure 12).[1] As detailed in Section 3.1, carbon pricing, with revenue returned to households *via* lump sum transfers, reduces the return on capital, initially lowers aggregate investment and decreases the neutral rate. In the detailed policy mix scenario, the fall in the neutral rate is partially mitigated by subsidizing green investment and carbon prices not being applied to all sectors. In particular, the investment subsidies raise the return on capital relative to the subsidized price of capital, raising the neutral rate.

**In the long term, the shift away from fossil fuels raises the capital intensity of production and the neutral rate relative to baseline.** The permanent implementation of emission reduction policies causes firms to rely more on capital and less on fossil fuel inputs, increasing the return on green capital. This green capital requires continuous investment, leading to a permanently higher investment to output ratio. As a result, the neutral rate increases after the initial decline to incentivize a higher household saving ratio from reduced incomes (see Figure 12, which extends Figure 10 to a longer time horizon).[2] Note that these changes in long run neutral rates abstract from potential long-term productivity benefits from increased green technology adoption or mitigated damages, that could put further upward pressure on neutral rates.[3] Furthermore, all scenarios assume that government debt is held constant relative to GDP. Lump sum transfers are the government's balancing item in all scenarios and are implemented to ensure the government's debt to nominal GDP is held constant.

…/…

Figure 12 **Neutral real rate under carbon pricing and detailed policies scenarios per region (over a longer time horizon)**

*(percentage points)*



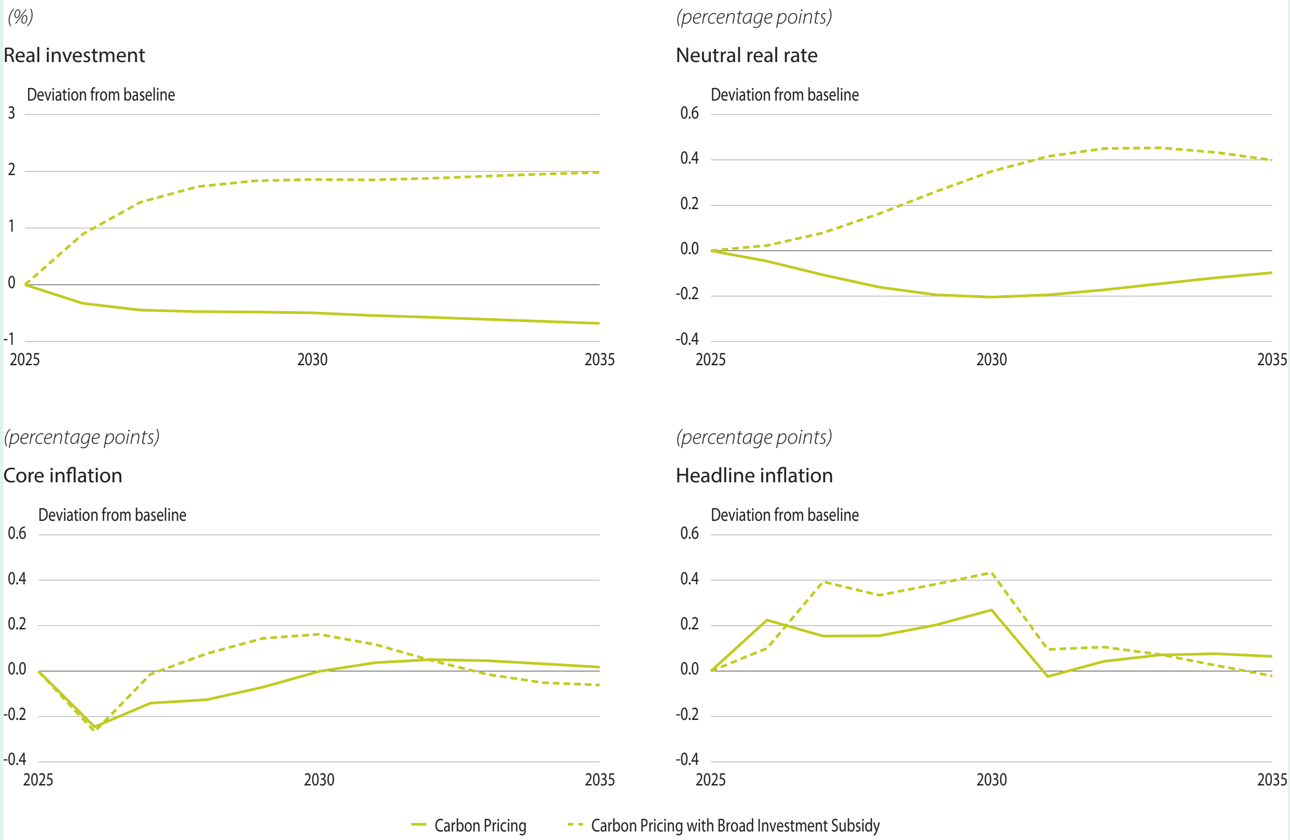

1 These results focus solely on the effects from transition policies, and present results as deviations from the baseline scenario. Impacts on r* overall accounting for other factors such as demographic changes and other region-specific developments might differ.

2 While movements along the capital demand curve associate higher capital to output ratios with lower neutral rates, carbon pricing cause a longer run shift in the capital demand curve, resulting in higher neutral rates.

3 This in part reflects GMMET's intended focus on the short- to medium-term effects of climate mitigation policies. While GMMET is intended to focus on short to medium impacts, its structural overlapping generation representation of households allows it to capture long run movements along the capital supply curve.

**If carbon pricing policies are accompanied by economy wide investment increases, the neutral rate may increase in the short to medium term.** The revenues from carbon pricing potentially provide significant resources that could fund programs to boost investment across the economy, more than offsetting negative impacts on aggregate investment from carbon pricing. Hence, we model a permanent *broad investment subsidy* that is introduced alongside carbon prices. The subsidy is calibrated such that revenue from carbon prices broadly equals subsidy expenditures over the first ten years.[4] The broad investment subsidy scenario thus assumes significantly larger subsidy expenditures compared to the targeted green investment subsidies of the detailed policies scenario. Accordingly, the broad investment subsidy raises aggregate demand and aggregate investment, as illustrated in Figure 13 for the Euro Area.[5] Higher returns from subsidized investments contribute to an increase in the neutral rate. Stronger aggregate demand results in higher inflationary pressure on both core and headline inflation compared to the carbon pricing scenario. The modelling shows similar effects across all the regions, illustrating the importance of government choices on the use of carbon tax revenues in shaping the macroeconomic effects, even if the underlying climate policy remains the same.

Figure 13 **Real investment, neutral real rate and inflation (core and headline) under carbon pricing and carbon pricing with broad investment subsidy (Euro Area)**




4 For the Euro Area, a subsidy rate of 8.5% is applied, corresponding to a subsidy expenditure of 2.3% of output. For comparison, carbon taxes raise revenues by 2.2% of output. Lump sum transfers continue to ensure debt-to-GDP ratio remains unchanged.

5 Patterns in other regions largely reflect impacts observed in the Euro Area under this scenario.

### 3.1.1 Monetary policy trade-offs under NDC-aligned Carbon Pricing Scenario

**The passthrough of carbon prices to higher headline inflation alongside weaker aggregate demand and decline in output creates trade-offs for monetary policy.** The relative price shift under carbon pricing creates a permanent structural wedge between the price of the core bundle of goods and the headline bundle. The trade-off is illustrated by comparing central banks looking through the first-round effects on headline inflation from carbon prices (implemented in the model as *core inflation targeting*) with headline inflation targeting, as discussed in the scenario description section 2.2. Under the 'looking through' approach, central banks lower their nominal policy rates in all regions, except for Oil Exporters, where core inflation increases (see Figure 2). This response reflects the decline in the neutral rate and core inflation remaining at or below central bank targets. However, this approach may be unsuitable when higher headline inflation persists over several years, raising the risk of second round effects. Figure 14 and Figure 15 contrast this with headline inflation targeting during the phase-in of carbon prices. In this latter case, central banks in the Euro Area and Oil Exporters tighten monetary policy relative to *core inflation targeting*. While this brings headline inflation closer to target, it comes at the cost of larger output losses, illustrating a trade-off for monetary policymakers. Thus, headline inflation targeting leads to a higher loss in GDP, compared to core inflation targeting. Figure 14 and Figure 15 also include GDP results in a model run with flexible prices to show contrasting outcomes for an additional illustration of the efficacy of monetary policy.

**These monetary policy trade-offs are most apparent for the Euro Area and for Oil Exporters.** In the Euro Area, more ambitious emission-reduction objectives and higher carbon prices contribute to larger increases in headline inflation. For Oil Exporters, the inflationary impact is most pronounced due to their fossil fuel-intensive economic structures and exchange rate effects. The decline in fossil fuel exports leads to currency depreciation, which generates strong inflationary pressures from higher import prices. In contrast, China and the Rest of the World experience smaller monetary policy trade-offs, since inflationary impacts are limited. In China, this reflects a relatively limited need for

Figure 14 **Headline and core inflation targeting under carbon pricing (Euro Area)**

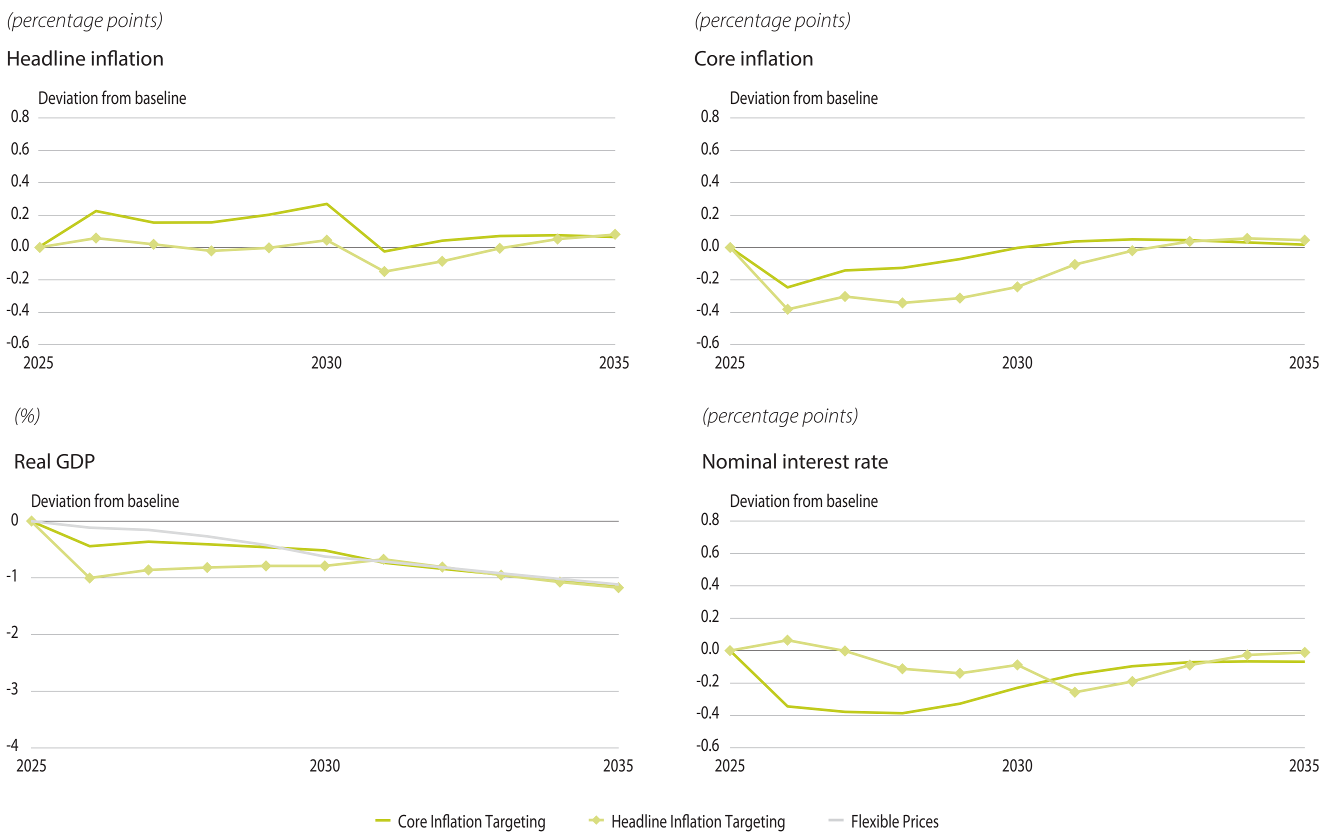
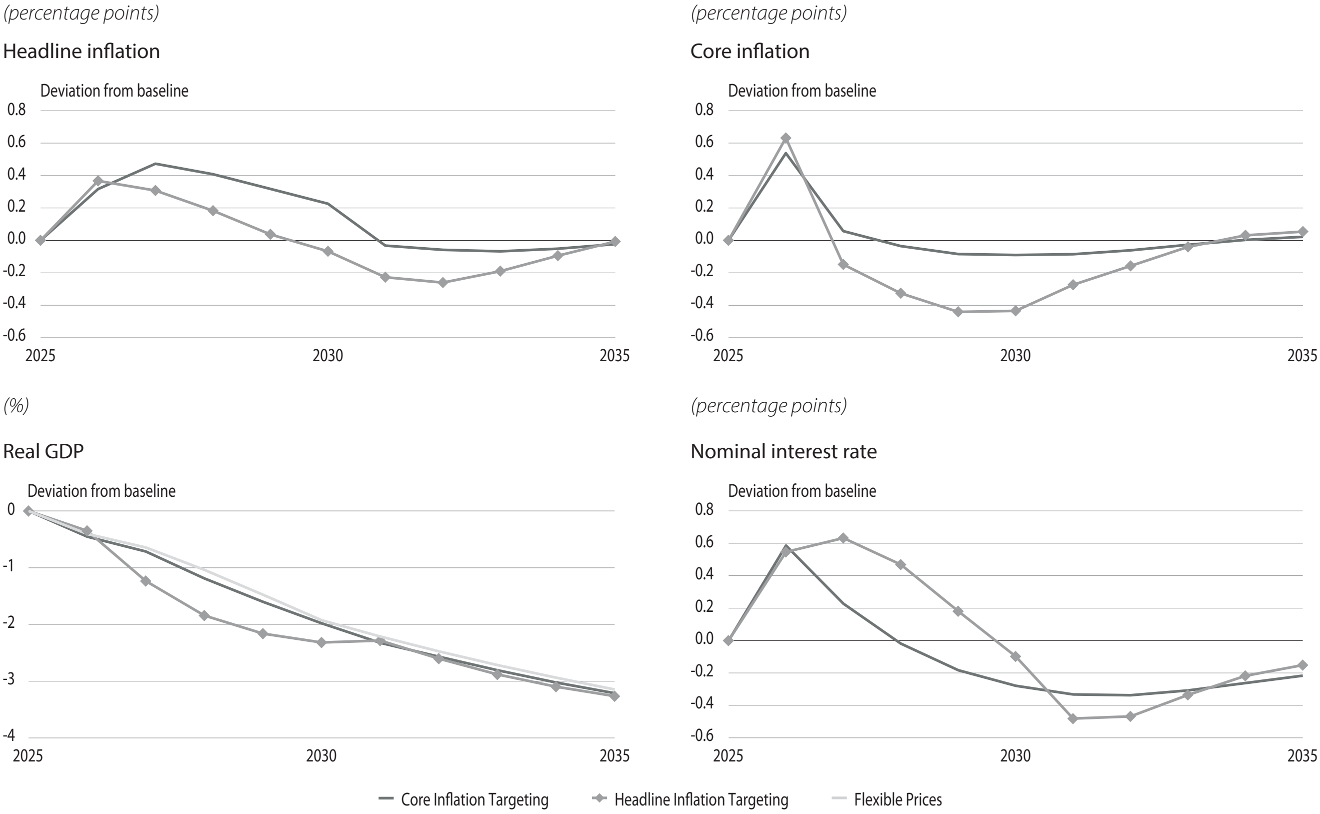


Figure 15 **Headline and core inflation targeting under carbon pricing (Oil Exporters)**




additional mitigation measures compared to the policy ambition in the baseline scenario. Since the analysis compares the baseline of current mitigation policies with carbon prices required to achieve the NDC targets, the additional impact depends on the gap between the existing policy ambition and that aligned with the region's NDC, which in China's case is relatively small. For the Rest of the World block, the diversity of economic structures across countries produces a complex picture, resulting in a modest aggregate trade-off.

## 3.2 Macroeconomic effects of an NDC-aligned Detailed Policy Mix Scenario

**The impact of the detailed policies (DP) scenario[34] is similar to the carbon pricing (CP) scenario,[35] though investment and GDP are generally higher, and inflation impacts are more complex.** While effects on exchange rates are similar to the CP scenario, green investment subsidies raise investment, GDP, and the neutral real rate relative to the CP scenario, under the same starting assumption of monetary policy 'looking through' first-round effects on energy prices. Renewable generation and building insulation subsidies raise the capital stock and supply, reducing inflationary pressures. EV subsidies directly lower headline inflation in implementing regions. Core inflation dynamics closely resemble those under the CP scenario. However, as the detailed policy mix scenario also includes carbon pricing, it still reduces GDP compared to baseline, and consumption is generally lower than under the CP scenario in the short to medium term.

**The combination of mitigation policies is important for inflation outcomes.** Direct effects depend on specific regional policies, such as green investment subsidy levels, the type of policy used to incentivise EV uptake, and carbon price increases, combined with regional economic structures and consumption baskets. Mitigation policies can have offsetting effects: while carbon prices raise headline inflation, EV rebates reduce it, and so do renewable investment subsidies over the medium term

34 See Annex Table 6 for more detail on the detailed policies assumptions.

35 The comparisons throughout are with the stylized Carbon Pricing scenario (see chapter 3.1) which assumes carbon tax revenues are recycled to households via lump-sum transfers.

Figure 16 **Headline inflation under CP and DP per region**

*(percentage points)*


through reduction in electricity prices, with the aggregate effect depending on the magnitudes and timing of these policies (see also NGFS, 2024c). Inflationary pressures are moderated by lower, though still positive, nominal wage growth resulting from weaker labour demand. Both real and nominal wages, while continuing to grow, are lower relative to baseline, but experience generally smaller declines under DP than CP, with only China initially seeing an initially steeper decline in real wages, as shown in Figure 17. Falling fossil fuel producer prices (excluding the carbon price component) and green energy generation subsidies, which reduce electricity prices in implementing regions, further moderate inflationary pressures.[36]

**Overall, different mitigation policy mixes lead to notable differences in inflation dynamics across regions.** Under both CP and DP, Oil Exporters and the Euro Area experience more persistent increases in headline inflation during carbon price phase-in.

- In the Euro Area, headline inflation drops slightly initially, unlike in the CP scenario. This temporary decline reflects a combination of factors, chiefly exchange rate appreciation in the initial period due to anticipated carbon price increases, and a drop in global energy demand, particularly for oil, lowering energy prices. Under the DP scenario, carbon price increases under ETS2 scheme begin in 2027,[37] unlike the assumption of uniform carbon pricing starting in 2026 (with anticipated gradual increases over a five-year phase-in period) in the CP scenario. Overall, the DP lead to a shorter period of above target headline inflation for the Euro Area.
- Headline inflation for Oil Exporters is more contained under DP, since regulation – which lacks direct emission price pass-through[38] – plays a greater role. However, currency depreciation, the shift to EVs, higher electricity prices, and regulation driving costlier production processes all contribute to inflationary pressures. Headline inflation in both the Euro Area and Oil Exporters eventually drops once the carbon prices are fully phased in by 2030.

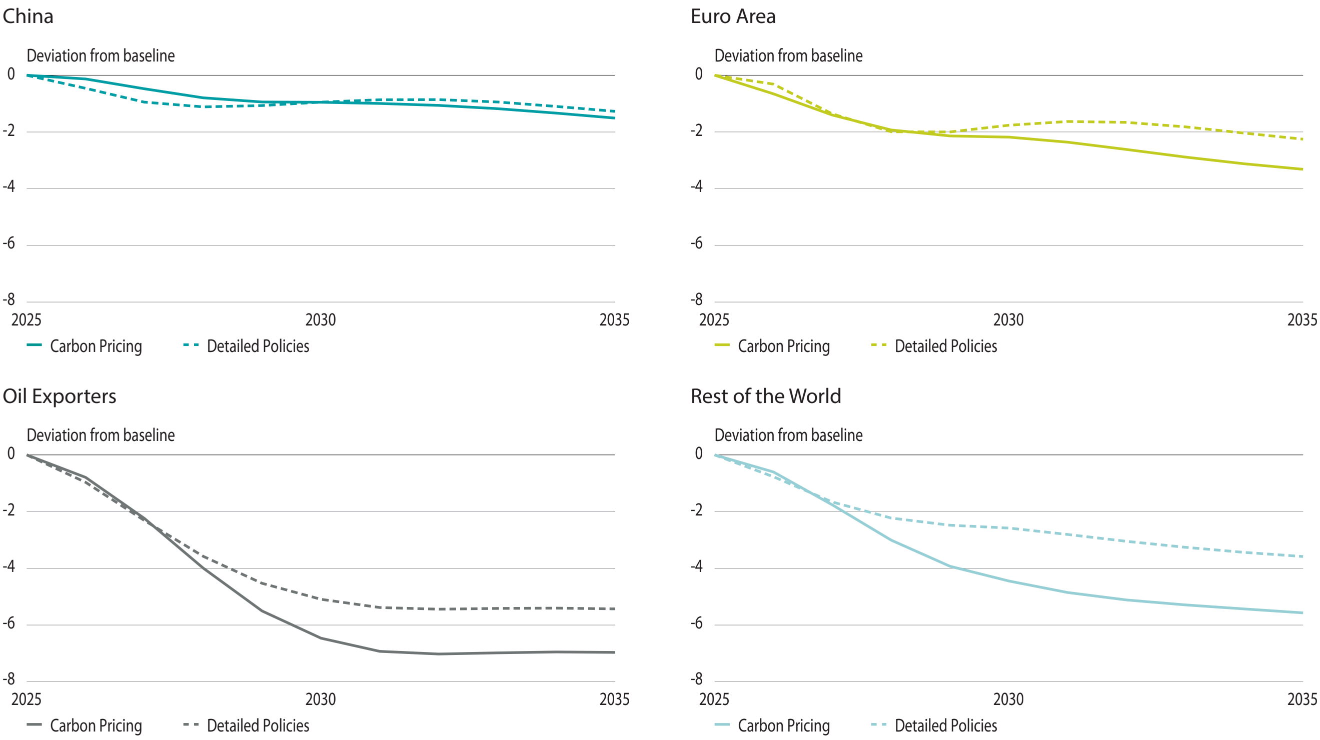
36 GMMET does not explicitly model the prospective long-term increases in firm or sectoral productivity that are expected to result from constantly improving emissions reduction technologies.

37 Note that 2027 reflects the initial EU legislation on ETS2, which is currently in the process of being postponed to 2028, following decisions by the Council of the EU and the European Parliament in November 2025.

38 Prices can still rise as input shares change.

Figure 17 **Real wages under CP and DP per region**

*(%)*




- In contrast, China experiences marginally higher headline inflation under DP than CP, mainly due to higher electricity prices from removing subsidies on coal inputs to energy generation.
- Meanwhile, the Rest of the World block experiences a substantial initial drop in headline inflation under DP, reflecting assumptions about how these diverse economies achieve their NDC targets. This deflationary pressure primarily results from green subsidies – covering 40% of renewable energy capital costs and covering 30% of EV purchase prices – which outweigh phased-in carbon price impacts.

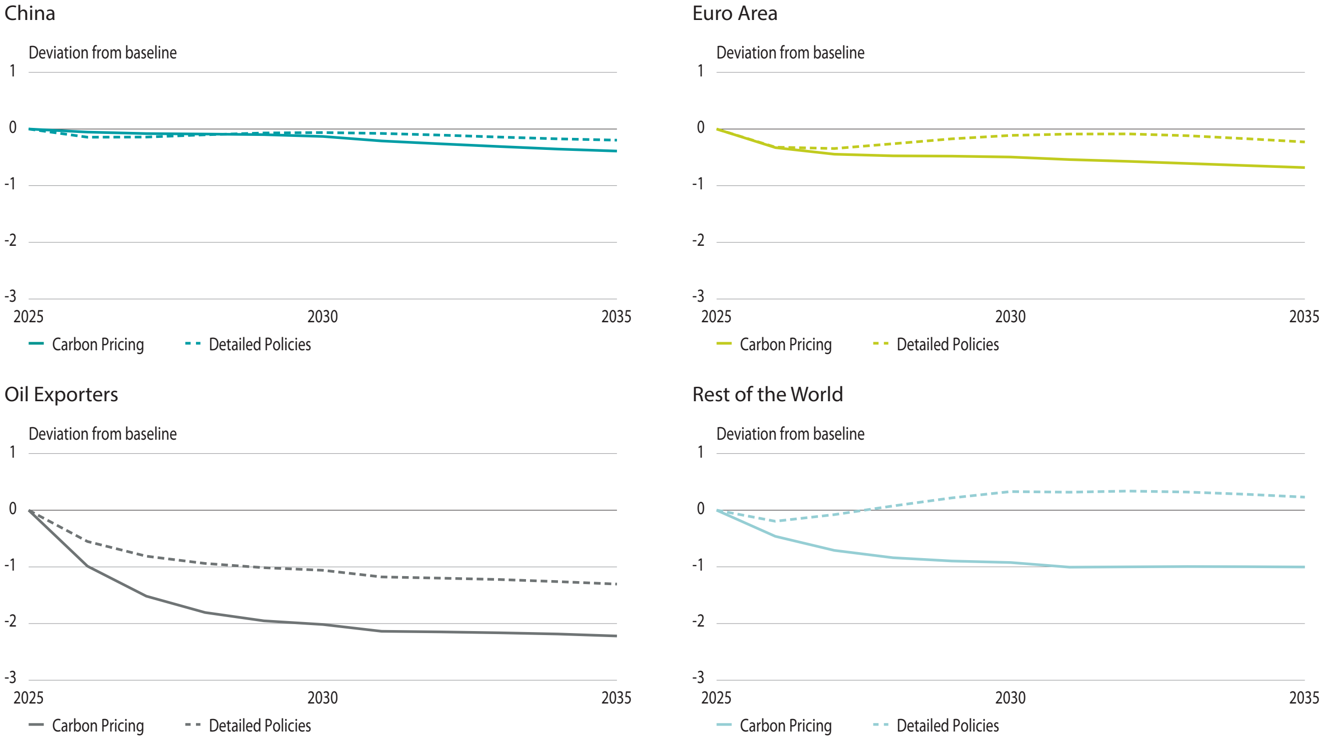
**Aggregate investment varies by region but is higher across all regions compared to the CP scenario.** Under DP, in all regions except China, a portion of revenue from carbon prices is used to subsidise renewable energy investment and for EV purchase rebates.[39] These subsidies increase capital formation primarily through clean technology investment, alongside the shift in relative prices present under both DP and CP.[40] Where introduced, subsidies for renewable generation investment, building insulation, and EV purchases increase the capital stock and supply in supported sectors. These increases in supply decrease prices and crowd out high-emitting sources. Importantly, the detailed policy mix also contains carbon pricing in some sectors, driving down high-emitting and other capital through the mechanisms discussed in section 3.1. Figure 18 shows that aggregate investment is higher compared to the CP scenario, as subsidies to green investment partially offset reductions driven by carbon pricing in other sectors.

39 Lump sum transfers are the government's balancing item in all scenarios and are implemented to ensure the Government's debt to nominal GDP is held constant. Under CP scenario, lump sum transfers to households take place in all regions. Under DP scenario, in regions where policy mix includes green subsidies – which is the case in all regions apart from China – a proportion of carbon pricing revenues is directed towards those subsidies.

40 The impact of the subsidies depends on which sectors they are introduced. Subsidies in upstream sectors such as electricity reduce input costs for users and thereby lead to greater increases in other investment. .

Figure 18 **Real investment under CP and DP per region**

*(% of GDP)*




**In the Euro Area, China and Rest of the World, aggregate real investment rebounds after the initial decline.** While the Euro Area and China see aggregate investment drop, impacts in both cases are relatively small compared to the CP scenario. In the Euro Area this in part reflects a positive role of subsidies for renewable energy capital.[41] In China, two factors drive this rebound. Firstly, removing coal subsidies under DP concentrates economic change in the coal sector, requiring greater investment in cleaner alternatives. Second, non-coal fossil fuels used in manufacturing face no carbon tax burden, since this scenario is focused on the phase-out of coal subsidies (see Table 6 in the Annex). As for Oil Exporters, they experience persistent investment declines, though smaller than under the CP scenario, due to a mitigation policy mix including regulation and subsidies, which partially offset the effects of carbon prices. Conversely, the Rest of the World block sees its investment rebound to a level above the baseline, driven by green investment and EV subsidies.

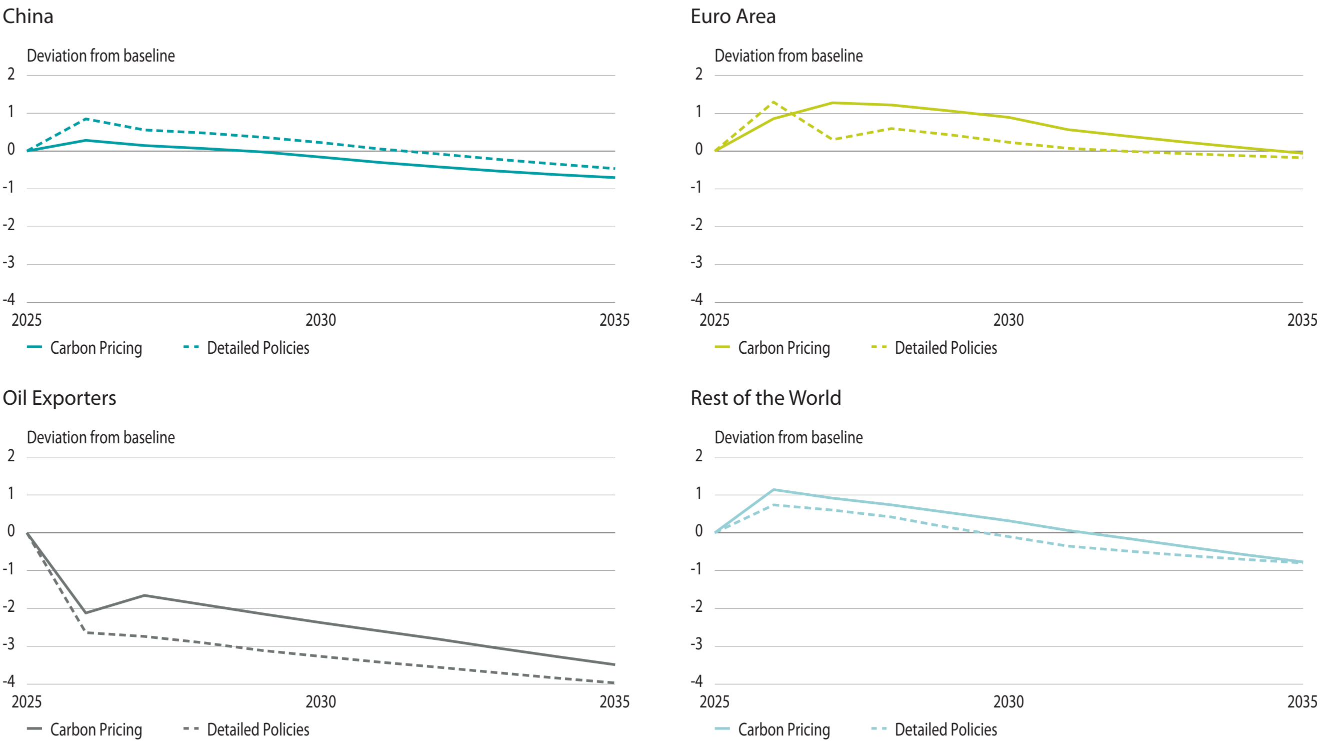
**Real consumption is lower in the near and medium term under the DP scenario as the share of investment in aggregate demand is higher** (see Figure 19). Real rates faced by households are on average higher under the detailed policies, ensuring increased investment is offset by decreased consumption. As in the CP scenario, Oil Exporters face the largest consumption declines, while other regions show minimal deviation from baseline after an initial increase. Over time, supply under DP is sufficiently higher from the increased investment to afford extra consumption.[42]

41 As highlighted earlier, the impact on investment depends not only on the domestic policy package but also on whether the Rest of the World block takes mitigation action. Using also GMMET but focusing only on the EU, Carton *et al.* (2026) find that total investment increases materially in a scenario where the EU meets its emission reduction objectives unilaterally.

42 In some regions, consumption under the DP rises above that under CP after 2035.

Figure 19 **Real consumption under CP and DP per region**

*(%)*

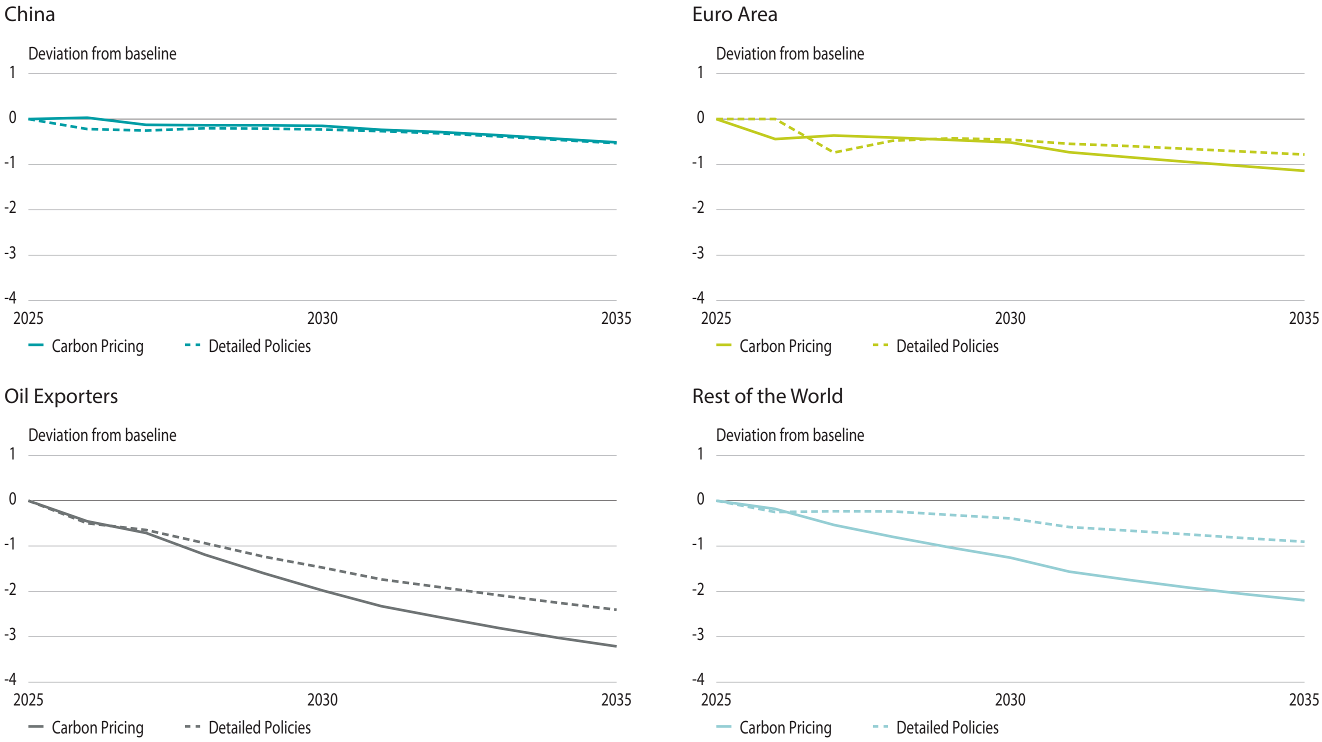



**In the DP scenario, potential output declines over the monetary policy horizon, but compared to the CP scenario, real GDP is higher in the medium term due to higher capital accumulation from investment subsidy in all regions except China** (see Figure 20). The more narrowly targeted emission reduction policies in China result in higher energy costs and lower GDP. Lower fossil fuel utilisation contributes to slower potential output growth compared to the baseline, as existing fossil fuel-intensive capital becomes less productive with higher carbon prices and mining rents are reduced. However, green investment subsidies – where implemented – partially offset these adverse effects compared to the carbon pricing scenario. Oil Exporters experience the largest output declines due to reduced investment, declining export revenues, and exchange rate depreciation, though detailed policies mitigate these impacts.

**While the detailed policies may appear to have more favourable GDP and inflation impacts compared to carbon pricing, this analysis does not assess which mitigation policies most efficiently achieve the reductions in GHG emissions from a welfare perspective.** The two scenarios and their variants focus on providing insight into monetary policy trade-offs that may arise in the near to medium term. As such, we do not undertake a welfare comparison of the mitigation policies. As recognised in the literature (see e.g. Parry *et al.*, 2022; Chateau *et al.*, 2022; van den Bergh & Botzen, 2024), carbon prices offer the most efficient tool for cutting emissions and remain the key driver of emission reductions in both scenarios, with the main difference being how carbon tax revenues are used. The detailed policies involve government resources raised from carbon taxes partially recycled into green subsidies, with the remaining revenue redistributed to households, and lump sum taxes covering any initial carbon tax revenue shortfalls to finance the subsidies. The analysis does not evaluate alternative uses of revenue from carbon pricing, which could be employed to ease fiscal pressures or support other government priorities.

Figure 20 **Real GDP under CP and DP per region**

*(%)*




### 3.2.1 Monetary Policy Response and Trade-offs under detailed policies

**The inflation-output trade-offs for monetary policy under the DP scenario are somewhat smaller, notably in the Euro Area and for Oil Exporters.** Similar to the CP scenario, the DP scenario creates a permanent structural wedge between the price of the core bundle of goods and the headline bundle. However, the gap between headline and core inflation is generally smaller compared to CP. The gap is smaller because, excluding China, detailed policies push up energy costs to a lesser extent, while effects on core inflation are similar. Figure 21 and Figure 22 contrast central banks looking through the energy-related first-round impacts from climate policies (implemented as core inflation targeting) with headline inflation targeting in the DP scenario for the euro area and oil exporters. Under headline inflation targeting, central banks in these regions react to higher inflation by tightening monetary policy. This approach keeps headline inflation closer to target, but again at the cost of larger output decreases, illustrating the trade-off over the monetary policy horizon.

**For China and the Rest of the World block (not shown), monetary policy trade-offs are less apparent.** In China, the gap between the baseline scenario and additional mitigation policies needed to meet its NDC is small, resulting in relatively small impacts and in turn limited trade-offs from the implementation of those extra policies. Finally, the diversity of economic structures within the Rest of the World block produces a complex picture with impacts on headline inflation that are closer to core inflation than for other regions, resulting in a small aggregate trade-off between whether the central bank targets the headline or looks through by targeting core.

Figure 21 **Headline and core inflation targeting under DP (Euro Area)**

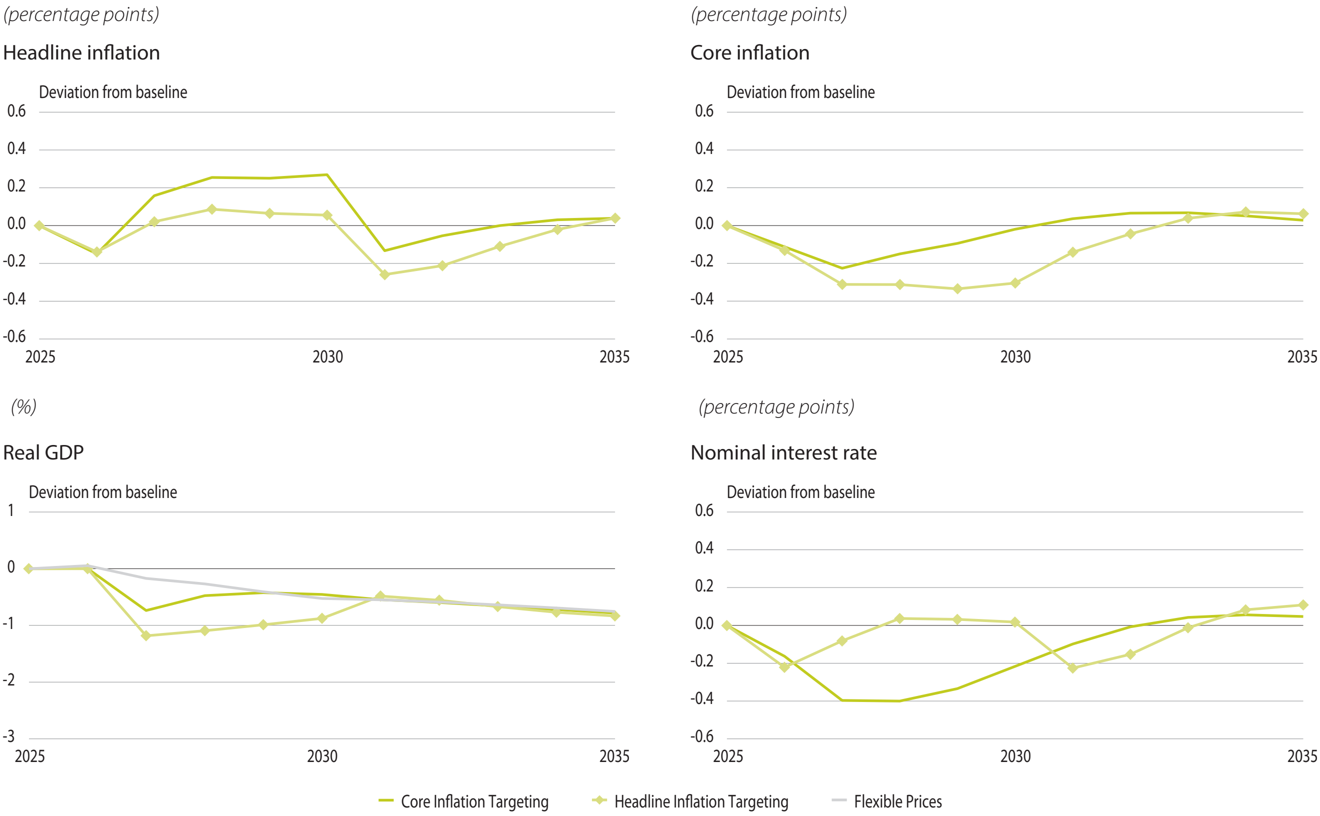
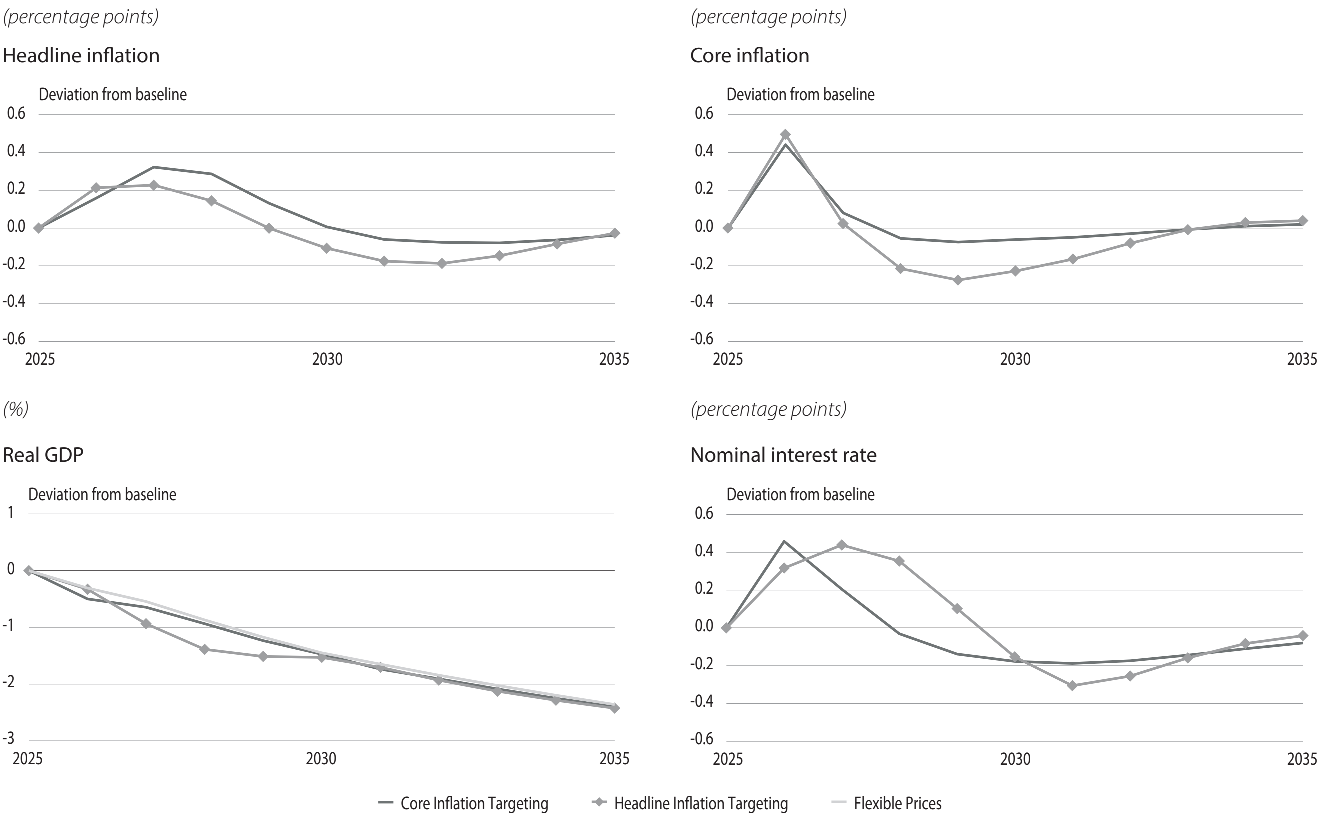



Figure 22 **Headline and core inflation targeting under DP (Oil Exporters)**



## Box 2

### The role of expectations and climate policy credibility: unanticipated implementation of carbon prices

*Whether agents behave in a forward-looking manner in response to the introduction of multi-year mitigation policy commitments and whether these commitments are seen as credible, plays a major role in shaping the macroeconomic effects under transition scenarios. Compared to the results presented throughout this report, an alternative scenario where consecutive carbon price increases to reach NDC targets are unanticipated (implying that agents do not foresee future mitigation policy changes or that announced future policies are not seen as credible) suggests trade-offs faced by the central bank might become more acute. Most regions experience higher initial inflationary effects alongside a more linear decline in GDP, while at the same time, the emissions mitigation is reduced over the scenario horizon (relative to the case in which agents anticipate increasing carbon prices) due to muted early investment responses[1]. This analysis shows that credible and anticipated transition policies help to mitigate possible adverse macroeconomic effects.*

**Analysis of climate mitigation policies often assumes that announced climate policies are perceived to be credible and that current decisions align with anticipated future outcomes; this assumption of credibility is significant for results in this modelling exercise.** Forward-looking reactions to future mitigation policies are a real-world aspect of their impacts: firms are investing in and researching low-carbon technologies, partly in anticipation of such policies. Many macroeconomic models – including GMMET – adopt rational expectations and perfect foresight. These assumptions help us to study forward-looking effects of mitigation policy changes, though they are also implemented for tractability and internal model consistency. However, government policy announcements are not always credible, as policies can change due to the shifting political environment and policy priorities, and economic agents are neither fully rational nor perfectly foresighted. These strict assumptions are important for certain model results. If agents fully anticipate long-term increases in carbon prices and expect associated income reductions, aggregate demand and inflation may initially decline (see Box 3 in Burgert *et al.*, 2025; Ferrari & Nispi Landi, 2024). The GMMET model is typically solved assuming full mitigation policy credibility, as in the main body of this report. Under these assumptions, increasing carbon prices leads to aggregate demand decreases and initial deflationary pressures on core prices in GMMET. Nevertheless, scenarios where mitigation policies lack credibility, or agents do not anticipate future implementation or are not completely forward looking, may be more realistic in some circumstances.

**Here we analyse an alternative illustrative scenario, where the carbon price increases during the policy phase-in are unanticipated.** Carbon pricing is introduced following the same path as in the main carbon pricing scenario, in a staggered manner over 5 years, but at each step, we make a stylized assumption that agents do not anticipate future increases but rather expect the carbon prices to remain constant from the point of each individual increase onward. As before, we start with an assumption that central banks look through impacts of carbon prices on headline inflation and then compare the effects with central banks tightening policy in response.

**Under the unanticipated carbon pricing scenario, GDP is somewhat less adversely impacted than under anticipated (credible) carbon pricing.** This is primarily driven by investment dynamics, where necessary shifts needed to deliver the transition are delayed, which lessens the near-term impacts but implies a more abrupt adjustment later if the NDC emission reduction targets are to be achieved. When future mitigation policy is credible, carbon-intense and other investments are reduced in the early years in expectation of higher future carbon prices and lower future returns. When higher future carbon prices are not anticipated the reduction in investment is smaller. Similarly, there is a smaller increase in green investment when mitigation policy is not credible. Overall, there is a smaller near-term decrease in aggregate investment when policy is not credible and the declines in aggregate demand and GDP are also smaller.

…/…

1 I.e. The carbon prices implemented at the same level that achieves NDC goals when policies are anticipated, fail to meet the NDC targets when agents do not anticipate them, which in turn delays their economic reactions.

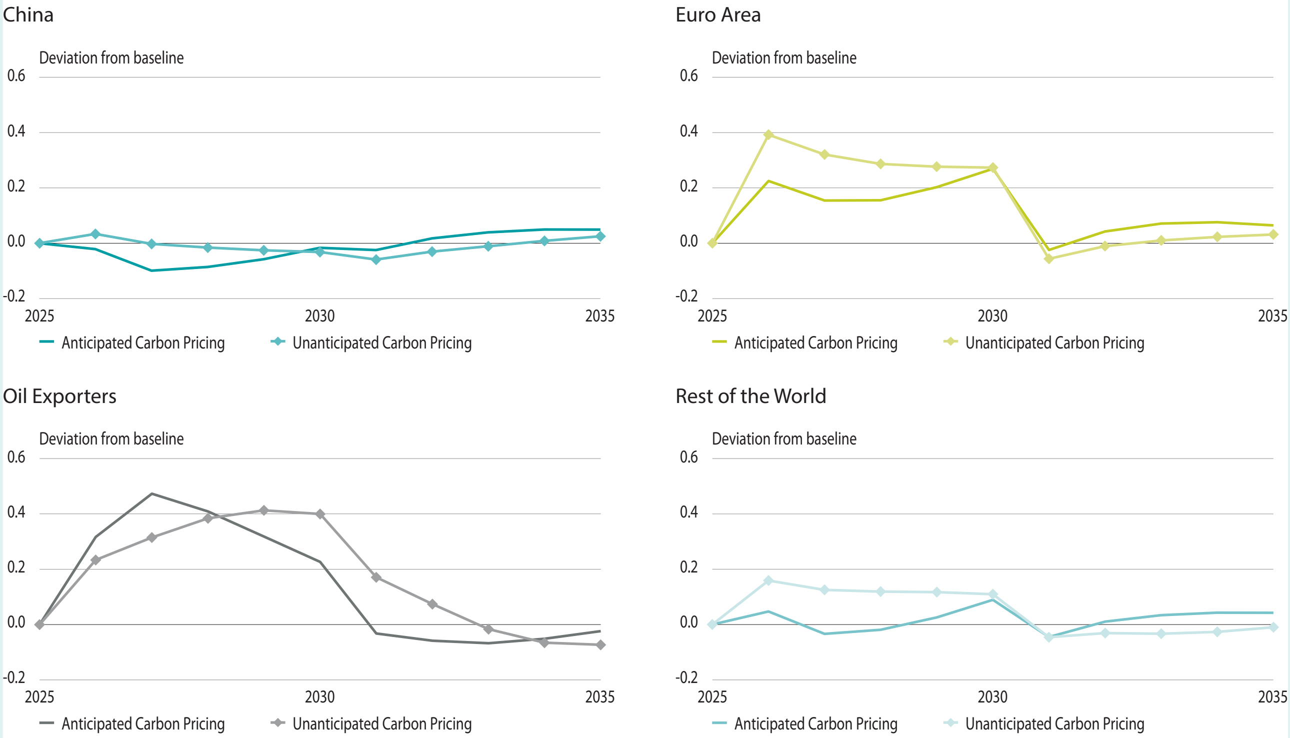
**Headline inflation is higher in all regions except for Oil Exporters under unanticipated phase-in of carbon prices** (see Figure 23). The inflationary impacts of unanticipated mitigation policy vary from the expected policy primarily due to two channels. Firstly, as above, the smaller initial decline of investment under unanticipated climate policy leads to a smaller initial fall in aggregate demand. Secondly, expected higher future carbon prices result in an immediate appreciation in the exchange rate (and depreciation for Oil Exporters); which does not occur when future mitigation policy is not expected. This contributes to higher core and headline inflation during the phase-in of carbon prices under unanticipated mitigation policy in all regions except for Oil Exporters (see Figure 24). In that country group headline and core inflation rise less steeply under unanticipated policy as the exchange rate drops less sharply, with headline peaking later than under anticipated policy.

**As the drop in core inflation is weaker and the estimated neutral rate is higher under unanticipated carbon pricing, central banks cut nominal interest rates by less.** The exception is again Oil Exporters where the central bank does not need to respond to a sharp upfront exchange rate depreciation and instead keeps nominal rates higher for longer to counter the ongoing depreciation over the first 5 years.[2]

**Under headline targeting, unanticipated carbon pricing also pushes headline inflation higher compared to when such policies are anticipated.** Moreover, when the central bank targets headline inflation rather than looking through by targeting core, under unanticipated climate policy, headline inflation in the euro area nonetheless rises 20bps above target, compared to being kept close to target under credible climate policy (Figure 25). This comes despite nominal interest rates being 30bps higher under unanticipated climate policy. …/…

Figure 23 **Headline inflation under anticipated and unanticipated carbon pricing per region**

*(percentage points)*

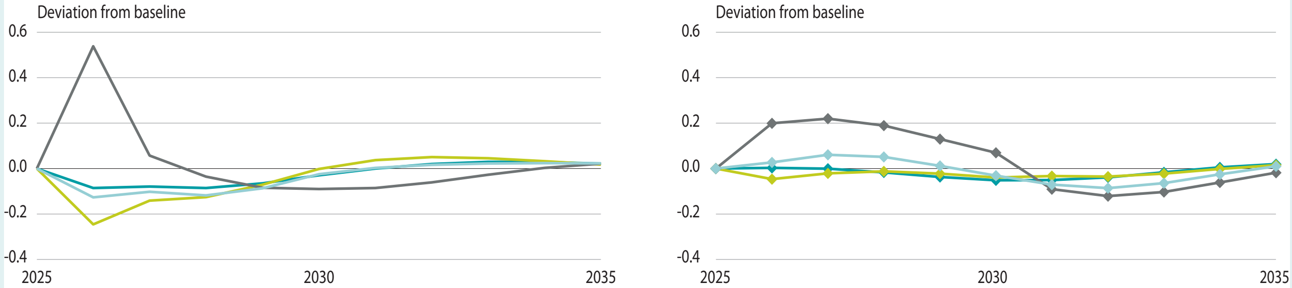



2 Expectations of interest rates are also relevant. When carbon price increases are not expected future interest rate cuts are not anticipated. Hence, households do not shift consumption forward to the same extent under unanticipated policy.

Figure 24 **Core inflation, nominal interest rate and real GDP under anticipated and unanticipated carbon pricing**

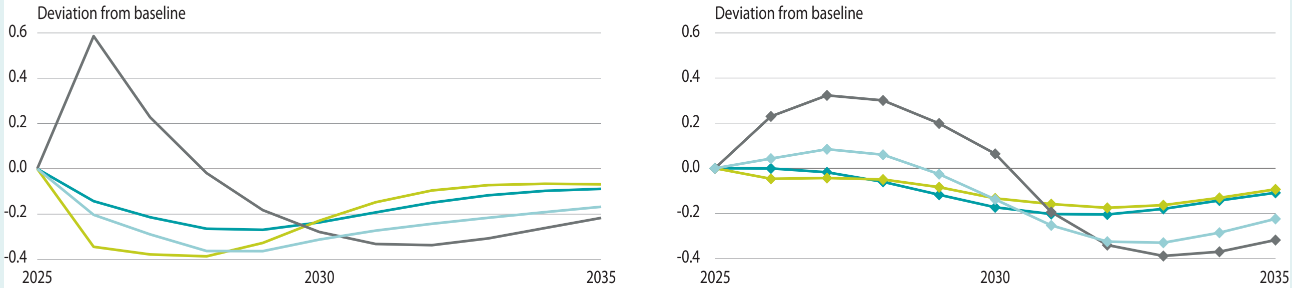
*(percentage points)* | *(percentage points)*

Core inflation (anticipated carbon pricing) | Core inflation (unanticipated carbon pricing)




*(percentage points)* | *(percentage points)*

Nominal interest rate (anticipated carbon pricing) | Nominal interest rate (unanticipated carbon pricing)




*(%)* | *(%)*

Real GDP (anticipated carbon pricing) | Real GDP (unanticipated carbon pricing)

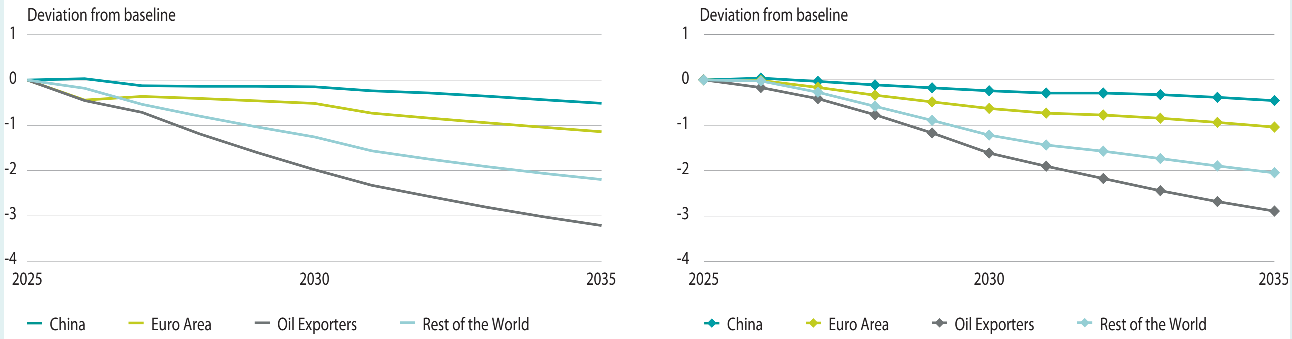
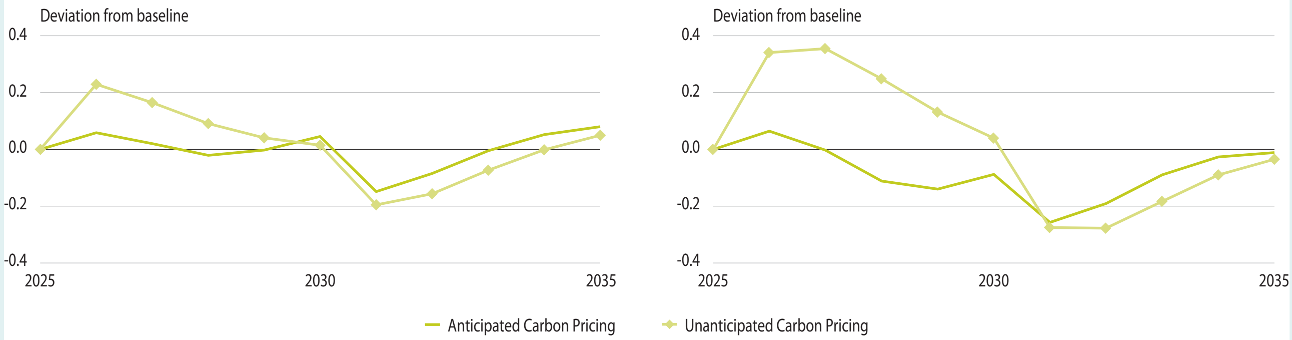



Figure 25 **Headline inflation and nominal interest rate under headline inflation targeting (Euro Area)**

*(percentage points)*

Headline inflation | Nominal interest rate



**Overall, the simulations suggest that if climate policies are not anticipated or not perceived as credible, central banks are likely to face stronger inflationary pressures from the introduction of additional carbon pricing policies.** While we do not model this dynamic explicitly, when climate policy lacks credibility, there is a more material impact on headline inflation, increasing the risk of second-round effects. In part, the findings also reflect generally higher costs when future climate policy is not anticipated, as firms are not able to optimize investments. Further, a lack of climate policy credibility compounded with backward-looking expectations by agents could imply even stronger inflationary effects. Equally, under such dynamics, real world emission mitigation action would be delayed, implying that either NDC targets would be missed or more stringent policies would be required at a later point in time which in turn could result in greater macroeconomic effects. Either way, central banks will need to be alert to the evolution of the transition pathways, agent behaviour and the implications for achieving their primary mandates from the resulting balance of transition and physical risks.

# 4. Conclusion

**The analysis in this report uses the IMF's GMMET model to explore implications of climate mitigation policies under NDC targets announced by governments over horizons relevant for monetary policy.** The analysis explores two mitigation policy scenarios: broad-based regionally varied carbon prices with revenue recycling to households, and a more detailed policy mix, compared to a baseline in which no further mitigation policies are introduced over and above policies already implemented. These scenarios do not incorporate the policies' effects on the physical impacts of climate change. Mitigated physical damages are discussed separately in Annex 1.

**The findings suggest that climate mitigation policies can lead to increases in headline inflation during the phase-in of carbon prices, while core inflation may fall in most regions, alongside a reduction in economic activity.** Under the assumptions of perfect foresight by agents, climate policies being credible and introduced in an orderly manner, the macroeconomic effects are relatively moderate. However, if mitigation policies are not credible or are unanticipated, inflationary pressures can be materially higher. If governments, in order to meet the Paris Agreement goals, pursue stronger policies than under the current NDCs, the macroeconomic effects would also likely be larger.[43]

**Carbon prices initially lower the neutral real rate as aggregate investment declines, though green investment subsidies can offset this decline.** Over the long run, higher capital intensity from green investments will tend to push the neutral rate up.

**The macroeconomic effects and the magnitude of inflation-output trade-offs depend on the specific mix of climate mitigation policies implemented and the underlying structures of economies.** The analysis shows that carbon prices generate inflationary pressures, mostly through direct pass-through to energy prices and increases in production costs. At the same time, demand side effects create deflationary pressures, as firms reduce investments in anticipation of reduced future demand.[44] Agents also expect the central bank to effectively act against inflation, keeping price expectations anchored. Economic structures determine exchange rate effects, which can significantly influence the overall size of trade-offs**,** exacerbating inflationary impacts for Oil Exporters, and dampening them in other regions.

**Central banks, in line with their remits, may need to balance these inflation-output trade-offs in determining how strongly they act to bring inflation back to target against the impact of tighter policy on output.** The illustrative approach when central banks 'look through' the first-round impacts of climate policies on inflation, modelled in the report as targeting core inflation, helps minimize output losses but results in higher headline inflation, risking larger second-round effects, particularly in an environment where central banks are dealing with other supply shocks too (Bailey, 2023; Greene, 2025). By targeting headline inflation, central banks bring inflation closer to the target, but at the cost of larger output losses compared to 'looking through' the initial inflationary effects of carbon prices. **A separate NGFS report (NGFS, 2026 forthcoming) will draw on this analysis to consider the monetary strategy implications of the impacts of climate change for monetary policymakers.**

**While mitigation policies can lower GDP and pose trade-offs for monetary policy, the longer-term economic benefits of these climate policies should mean that central banks will not have to deal with the increased economic volatility associated with the economic impacts of climate change in the long term.** As benefits from avoided damages accumulate over the longer term, they can offset initial declines in output from implementing NDC-aligned mitigation policies and produce a net positive impact on global GDP by approximately mid-century (see Annex 1). Faster improvements in green technology and other benefits from the transition not modelled in these simulations, such as higher productivity resulting from health improvements, could also contribute to faster growth.

43 Reductions to annual emissions of 35 per cent and 55 per cent, compared with 2019 levels, are needed in 2035 to align with the Paris Agreement 2 °C and 1.5 °C pathways, respectively compared to approximately 20% emissions reduction from policies modelled in this report. See UNEP (2025).

44 See Ferrari & Nispi Landi, 2024; see also Burgert *et al.,* 2025 for a model-comparison, and Box 2 for results under unanticipated implementation of policies.

# Annex 1

## Avoided Damages

*Results presented so far look at the effects of mitigation policies on GDP, inflation and monetary policy, without accounting for the reduction in climate-related physical impacts and associated economic damages that these policies are designed to achieve. Accounting for avoided damages corrects for this assumption and highlights the positive economic impacts of mitigation policies. Avoided damages associated with NDC aligned emission reductions could in isolation raise global GDP by around 0.3% in 2035. Over the longer term, gains from avoided damages begin to outweigh the costs of mitigation policies, with positive net global GDP impacts around mid-century.*

**When considering the macroeconomic impacts of mitigation policies, accounting for avoided damages provides a more complete picture.** Governments implement emission reduction policies to limit climate change-related losses; this reduction is referred to as avoided damages. Thus, while mitigation policies can lower GDP and pose trade-offs for monetary policy in the short- to medium-term, accounting for avoided damages highlights the medium- and long-term benefits of additional policy action (see e.g. NGFS, 2023).[45] While the world already experiences damages from climate change, the effects of additional mitigation policies will manifest over time as the effects of reduced emissions begin to materially affect the state of the climate system through reduced cumulative GHG atmospheric concentration.

**Estimates of economic damages from climate change in the literature vary widely.** Amplifying the resulting uncertainty, each individual study comes with its own uncertainty and estimates only a distribution of damages. While methodologies to assess future climate losses continue to evolve, no model can deliver precise forecasts of future climate damages, and such predictions should not be regarded as definitive.

**We calculate avoided damages using recent literature to translate changes in annual global emissions into productivity impacts.** We harness a two-step procedure. In a first step, emission cuts are mapped into avoided warming, following Dietz *et al.* (2021). In a second step, avoided warming is mapped into avoided output losses, based on Bilal and Känzig (2026). While there is a wide range of estimates on warming damages, their paper makes methodological improvements over previous studies finding larger damages from global warming than previous estimates.[46] It finds that 1 °C of higher temperatures reduce output by about 20% in the long run. Traditional estimates suggest output losses of about 1%-3% of GDP, by the end of the century, for a permanent increase in global temperatures by 1 °C (see Nordhaus (1992) for a seminal contribution or NGFS (2024a) for an overview of climate damages literature). For simplicity, we implement a TFP increase to match the empirically estimated avoided output losses, applied uniformly across regions. Over time, the rise in productivity accelerates due to gradually declining emissions (simulated policies cut annual emissions by roughly 20% after 10 years). This causes the stock of avoided emissions – determining avoided warming and damages – to grow at an accelerating pace. With each year that goes by, the cut is greater than previous cuts as the effects of mitigation policies are unfolding. Together with transmission delays (from emissions to warming and from warming to damages) this means that the improvements in productivity accelerate over time.

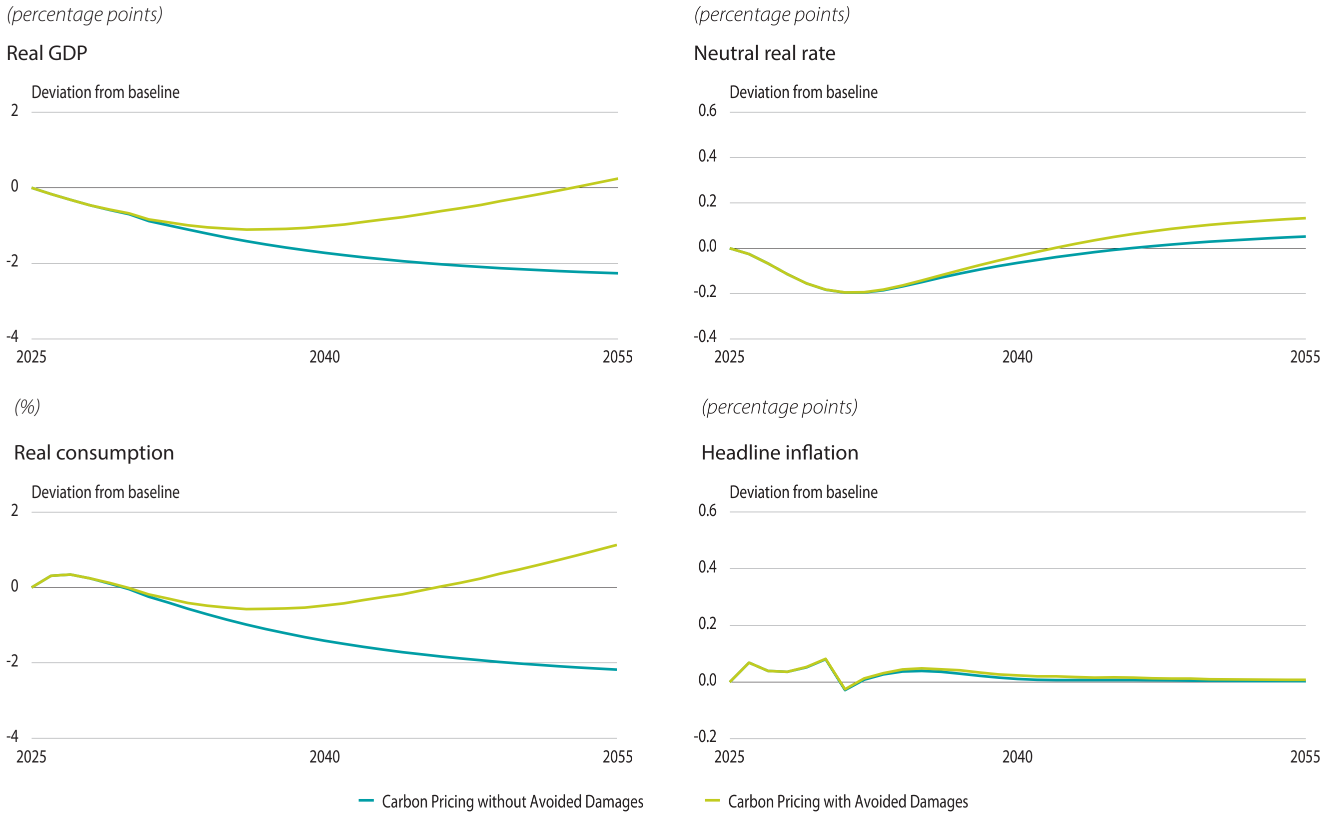
**The 10-year horizon masks that the policies' permanent cut in emissions translates into an ever-increasing stock of avoided emissions.** This translates into continuously growing avoided damages after emissions have adjusted. For example, in 2055, the policies will have shaved off close to 0.14 °C from the increase in global temperatures (relative to baseline), which translates into avoided damages of around 3% of global output.

45 NGFS Phase IV long term scenarios, 2023.

46 The key insight of Bilal and Känzig (2026) is that traditional studies focus on local temperature as driver for damaging extreme weather events, whereas the geoscience literature asserts that extreme weather is driven by global temperature. Focusing on global temperatures reveals warming damages that are by an order of magnitude larger than estimated in traditional studies.

**In the medium term, avoided damages could boost global average output by around 0.3% in 2035 with negligible inflation impacts.** Figure 26 presents global macroeconomic outcomes under the carbon pricing scenario with and without avoided damages. We assume agents do not anticipate higher productivity from avoided damages; they learn it about when it occurs in each period and expect that level of productivity to continue.[47] This reflects the notion that firms and households do not anticipate future warming damages, so that avoiding them has no impact on expectations. It is in line with evidence, for example, that markets do not fully embed long-term climate risk into prices (see for example Gourevitch *et al.*, 2023). Output effects of avoided damages remain negligible in the first 5 years of the modelled scenario, as annual emission cuts are initially modest and take time to accumulate. However, from around year 5 onwards, avoided damages grow at an accelerating pace, reflecting growing emission cuts and the accumulation effect. Investment and consumption rise roughly in line with output and there are almost no inflationary pressures as demand expands in line with supply. The neutral rate is higher in the medium to long run reflecting higher productivity from avoided damages which raises investment demand.

Figure 26 **Impact of avoided damages on real GDP, neutral real rate, real consumption and headline inflation under carbon pricing**




47 In any given year agents observe less climate-related physical damages due to climate action and from then on anticipate that this marginal reduction of damages, manifesting as increased productivity, will persist as the new norm going forward. But agents do not anticipate that in each subsequent year the benefits will continue to increase.

**Accounting for avoided damages results in positive longer run GDP impacts from NDC aligned mitigation policies.** After 25 years GDP is higher at global level.

**While avoided damages from NDCs have a limited impact on inflation over the next 10 years, on average, acute damages and climate-related shocks are likely to be relevant for monetary policy.** Here we consider the reduction in chronic damages from meeting NDC targets over the next 10 years. However, baked in warming from past and current emissions will likely cause a higher intensity and frequency of weather-related supply shocks (see NGFS, 2024a). These shocks, and their potentially higher frequency, can alter the path of output and inflation in the short run, which may require responses from central banks. For further discussion on monetary policy implications of physical risks, see (NGFS, 2024a; NGFS, 2026).

# Annex 2

## Annex to Section 2.1: Composition of Regional Blocks

Table 2 **Composition of Regional Blocks**

| | |
|---|---|
| **Euro Area** | Austria, Belgium, Croatia, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Portugal, Slovakia, Slovenia, Spain |
| **Oil Exporters**[1] | Algeria, Angola, Azerbaijan, Brazil, Cameroon, Canada, Chad, Colombia, Congo, Ecuador, Equatorial Guinea, Gabon, Ghana, Iran, Iraq, Kazakhstan, Kuwait, Libya, Mexico, Mongolia, Nigeria, Norway, Oman, Qatar, Russian Federation, Saudi Arabia, South Sudan, United Arab Emirates, Venezuela |
| **Rest of the World** | Afghanistan, Albania, Andorra, Antigua and Barbuda, Argentina, Armenia, Australia, Bahamas, Bahrain, Bangladesh, Barbados, Belarus, Belize, Benin, Bhutan, Bolivia, Bosnia and Herzegovina, Botswana, Brunei Darussalam, Bulgaria, Burkina Faso, Burundi, Cabo Verde, Cambodia, Central African Republic, Chile, Comoros, Costa Rica, Cote d'Ivoire, Cuba, Czechia, Democratic People's Republic of Korea, Democratic Republic of the Congo, Denmark, Djibouti, Dominica, Dominican Republic, Egypt, El Salvador, Eritrea, Eswatini, Ethiopia, Fiji, Gambia, Georgia, Grenada, Guatemala, Guinea, Guinea Bissau, Guyana, Haiti, Honduras, Hungary, Iceland, India, Indonesia, Israel, Jamaica, Japan, Jordan, Kenya, Kiribati, Kyrgyzstan, Lao People's Democratic Republic, Lebanon, Lesotho, Liberia, Liechtenstein, Madagascar, Malawi, Malaysia, Maldives, Mali, Marshall Islands, Mauritania, Mauritius, Micronesia, Monaco, Montenegro, Morocco, Mozambique, Myanmar, Namibia, Nauru, Nepal, New Zealand, Nicaragua, Niger, North Macedonia, Pakistan, Palau, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Poland, Republic of Korea, Republic of Moldova, Romania, Rwanda, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Samoa, San Marino, Sao Tome and Principe, Senegal, Serbia, Seychelles, Sierra Leone, Singapore, Solomon Islands, Somalia, South Africa, Sri Lanka, Sudan, Suriname, Sweden, Switzerland, Syrian Arab Republic, Tajikistan, Thailand, Timor-Leste, Togo, Tonga, Trinidad and Tobago, Tunisia, Türkiye, Turkmenistan, Tuvalu, Uganda, Ukraine, United Kingdom of Great Britain and Northern Ireland, United Republic of Tanzania, Uruguay, Uzbekistan, Vanuatu, Viet Nam, Yemen, Zambia, Zimbabwe |

1 Oil Exporters were selected as countries with net exports of crude oil consistently exceeding 1% of GDP over the three-year period of 2020, 2021 and 2022. Crude oil net export data is primarily sourced from the Observatory of Economic Complexity (OEC) and supplemented with data from the International Energy Agency (IEA). The selection also includes the 20 largest net oil exporters in absolute terms. Small Island Developing States (SIDS) and countries with significant data gaps are excluded.

## Annex to Section 2.2 (a): Approach to the projection of emission pathways – summary

Fundamentally, **two emission pathways per country block** were projected: a baseline pathway built on the assumption that no additional climate mitigation policies would be implemented and an NDC pathway capturing the emission effects of policy implementations sufficient to meet the targets specified in countries' Nationally Determined Contributions under the UNFCCC.[48]

**Baseline pathways** were projected based on the ten-year average annual emission (intensity) change for countries with absolute emission (emission intensity) targets.[49] Exceptions to this rule are the EU for which a five-year average was used to better account for the intensification of climate mitigation policies under the last Commission, Brazil for which a 15-year average was used to mitigate for data gaps, and Nigeria as well as Turkey and Indonesia which specify their own baselines in their NDCs. Where countries specify their own baselines up to 2030 only, the ten-year average annual emission change between 2021 and 2030 was linearly extrapolated out until 2035. Past emissions data up until 2022 was derived from national or regional GHG registries where specified in respective NDC submissions or otherwise taken from the Emissions Database for Global Atmospheric Research (EDGAR).[50] As China singles out $CO_2$ only for its NDCs, the $CO_2$ database provided by Friedlingstein *et al.* (2024) was used to obtain China's past emissions.[51] This baseline computation can be understood as a status-quo scenario in which mitigation ambitions remain constant and no mitigation policies with additional emission reduction effects beyond trends over the most recent past are being introduced.

48 NDCs were accessed *via* the UN's official NDC Registry: Nationally Determined Contributions Registry | UNFCCC.

49 Emission intensity was used for countries which specify their NDCs using such metric.

50 EDGAR – The Emissions Database for Global Atmospheric Research.

51 Global Carbon Budget | GCB 2024.

**NDC pathways** were computed based on a linear extrapolation of total emissions (emission intensities) between the most recent year for which historical emission data is available (typically 2022) and the target years specified in a country's or region's NDC submission, e.g. a net zero target for 2050 and an interim emission reduction target for 2030.

For country blocks comprising more than one entity with distinct NDCs, i.e. Oil Exporters and the Rest of the World, **proxy countries** were used due to resource constraints prohibiting a detailed pathway projection for each individual country. For Oil Exporters, countries with the biggest share of GHG emissions over the years 2018-2022 in their respective sub-regions were selected as proxies (see Table 3 below). For the Rest of the World, the five largest emitters overall were used to approximate the entire country block's emission pathways (see Table 4).

Table 3 **Proxy Countries for Oil Exporters**

| Sub-region | Proxy Country | Weighting | Country share in Oil Exporters block |
|---|---|---|---|
| **Arab** | Iraq | 31% | 3,1% |
| **Africa** | Nigeria | 8% | 4,0% |
| **Asia & Europe** | Russia | 29% | 24,3% |
| **Latin America** | Brazil | 25% | 12,8% |
| **North America** | Canada | 7% | 7,3% |
| **Total** | / | **100%** | **51,5%** |

Table 4 **Proxy Countries for the Rest of the World Block**

| Proxy Country | Weighting | Country share in Rest of the World block |
|---|---|---|
| India | 50.2% | 20.1% |
| Japan | 16.1% | 6.7% |
| Indonesia | 15.4% | 6.4% |
| South Korea | 9.8% | 4.0% |
| Türkiye | 8.5% | 3.5% |
| **Total** | **100%** | **40.7%** |

## Annex to Section 2.2 (b): Approach to determining detailed NDC policy mixes – summary

The detailed NDC mitigation policy mix for a regional block is constituted by two underlying factors: the sectoral distribution of GHG emission reductions and the mix of policy types to achieve said reduction. Each sector is treated with an individually determined policy mix. While GMMET does not cover all economic sectors, it accounts for sectors responsible for circa 85% of GHG emissions in any of the five model regions, allowing for a good approximation of emission reduction profiles. Where NDCs or closely associated government publications do not specify sectoral emission targets, sectoral contributions to country-level emission reductions were based on current sectoral emission profiles. For instance, if a country's energy sector currently accounts for 30% of its GHG emissions, it would be assumed that it will also account for 30% of the country's emission reductions. Mitigation policy types available in GMMET are price-based measures such as taxes or emission trading schemes (ETS), subsidies, and regulation.

In the case of the European Union, both the sectoral distribution of emission reductions and the policy types are well specified in official EU documents. Together, the EU ETS and ETS2 account for the majority of emission reductions with regulation and subsidies being more prominent policy levers in the transport and buildings sectors. China does not provide as much detail on sector profiles and policy types in its official NDC documents, relevant academic literature and statistical information on current policy mixes also instruct the NDC policy mix for China. In general, while a significant share of China's emissions is covered by its ETS which is set to further expand, subsidies and regulation remain important policy levers, especially in the transport and buildings sectors.

For Oil Exporters and the Rest of the World block, key policies outlined in NDC submissions or in public government announcements since the most recent NDC submission were collected to generate country-level policy profiles of the selected proxy countries (i.e. India, Indonesia, South Korea, Japan and Turkey for the Rest of the World block and Russia, Brazil, Nigeria, Iraq and Canada for Oil Exporters). Sectors were ranked according to their contribution to national GHG emissions.[52] Per country, the mitigation policy mix for each of the five most polluting sectors was subsequently identified. On the country block level, the six most polluting sectors and their policy mix were considered. The policy mix for each sector was obtained by applying the respective proxy country's weighting factor to the respective policy mix of the country in question. Given the lack of detailed policy proposal to achieve NDC pledges for some countries, past policies had to be chosen as guideline for determining the respective policy mix.

Table 5 **Carbon Pricing Scenario (informed by NDCs)**

| China | Euro Area | Oil Exporters | Rest of the World |
|---|---|---|---|
| \$30 carbon price phased in over 5 years | \$240 carbon price phased in over 5 years | \$55 carbon price phased in over 5 years | \$110 carbon price phased in over 5 years |

Table 6 **Detailed Policy Mix Scenario (informed by NDCs)**

| China | Euro Area | Oil Exporters | Rest of the World |
|---|---|---|---|
| Phasing-out of subsidy on coal burned in electricity generation worth \$25/t$CO_2$e (over 3 years) | Transport sector regulation in favor of EVs | Transport sector regulation in favor of EVs | Carbon prices of \$35/t$CO_2$e on fuels in electricity generation, \$40/t$CO_2$e on energy use in the energy intensive tradable sector, and \$90/t$CO_2$ on oil for heating, ICE gasoline, and energy use in the regular tradables sector (each phased in over 5 years) |
| Carbon price of \$40/t$CO_2$e (phased in over 3 years) on emission from gas in home heating, ICE gasoline use, gas in electricity, energy in energy intensive as well as regular tradable goods | ETS2: Carbon price \$400/t$CO_2$e (phased in over 4 years) on gas for home heating and gasoline for ICEs. Starting in 2027 and not anticipated beforehand | Electricity sector regulation against the use of coal | Emission penalty of \$90/t$CO_2$e (phased in over 5 years) on emissions not related to burning fossil fuels |
| | ETS: Carbon price \$375/t$CO_2$e (phased in over 5 years) on energy use in energy-intensive tradables sector as in electricity generation | Carbon price \$40/t$CO_2$e (phased in over 5 years) on energy use in energy intensive tradable goods[1] | Subsidy for renewables capital that covers 40% of the price |
| | Recycling of about half of ETS revenues: Subsidy for renewables capital that covers 55% of the price | Carbon price \$20/t$CO_2$e (phased in over 5 years) on energy use in regular tradable goods[2] | Subsidy on EVs of 30% of the purchase price |
| | Emission penalty of \$190/t$CO_2$e (phased in over 5 years) on emissions not related to burning fossil fuels | Emission penalty of \$50/t$CO_2$e (phased in over 5 years) on emissions not related to burning fossil fuels | Tax on ICEs of 10% of the purchase price that offsets the EV subsidy's impact on headline inflation and makes it close to revenue neutral |
| | Carbon price of \$175/t$CO_2$e on energy use in general tradable good sector (phased in over 5 years) | Subsidy on building insulation of 15% of costs | Subsidy on building insulation of 15% of costs |

1 Modelling assumes that non-regulated sectors don't increase emissions in response to cheaper fossil fuel prices.

2 Ibid.

52 GHG emissions per sector and per country retrieved from Our World in Data: $CO_2$ Country Profile – Our World in Data: Breakdown of carbon dioxide, methane, and nitrous oxide emissions by sector – Our World in Data.

## Annex to Section 2.2 (c): Implementation of looking through or responding to policy induced inflation rise

We run two assumptions of the central bank's monetary policy rule, to illustrate the trade-off faced by central banks. The first case assumes the central bank looks through the climate policy induced rise in headline inflation. This is implemented by a Taylor rule that targets core inflation which excludes energy prices and ignores measures that directly affect consumer prices, such as EV subsidies.

The second case examines the central bank responding directly to changes in headline inflation. In implementing this version in the model, it is assumed that agents expect the central bank to look through energy driven inflation rises. Hence agents are surprised by the tighter monetary policy response implied by responding to headline-inflation. This modelling assumption helps ensure the differences in the two versions of the scenario are not driven by agent expectations of future monetary policy, which can lead to counterintuitive results. Assuming different expectations of future monetary policy responses would make the comparison and trade-offs difficult to interpret. When a different monetary policy reaction is expected, both inflation and nominal interest rates can be lower in the early periods due to expectations of tighter policy later in the scenario. Targeting headline inflation unexpectedly in each period removes this effect, which is also known as the "forward guidance puzzle". Under looking through policy, the monetary rule applies a 70% weight to current and 30% weight to next period core inflation, making the central bank somewhat forward looking. Under responding policy, the rule applies a 100% weight to current period headline inflation, essentially making the central bank more responsive to energy prices within the current year.

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