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The case for adaptive inflation targeting: monetary policy in a hot and volatile world

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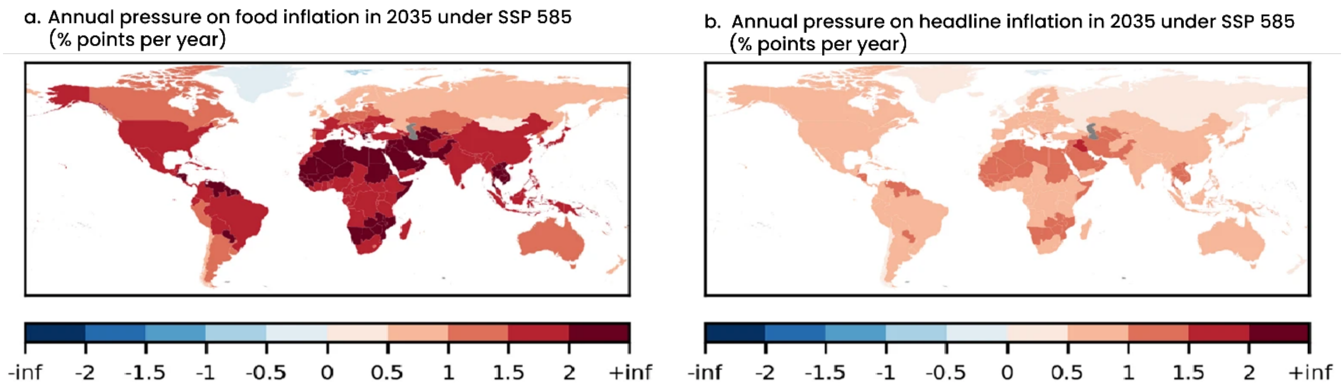
Summary

Negative supply shocks caused by climate change and interconnected crises may increasingly fuel persistent inflationary pressures. Responding to these shocks with standard monetary tightening would involve significant trade-offs, including impacts on economic output, financial stability, fiscal space, income equality and the green transition. While flexible inflation-targeting (FIT) regimes have faced supply shocks in the past, central banks may encounter new challenges in assessing and responding to these trade-offs, particularly when it comes to long-term macroeconomic stability. Consequently, we believe the time is right for a policy discussion on adaptive inflation targeting ('adaptive-IT'), which aims to equip central banks with a framework, analysis and toolkit that enables them to better navigate these supply-side disruptions. To preserve their credibility and ensure the smooth implementation of possible changes to their existing inflation-targeting regimes, central banks must communicate these changes clearly in times of relative stability.

Rising inflationary risks in a hot and volatile world

Physical hazards from climate change are already generating short-term inflationary pressures through their negative impacts on the supply side of the economy. Food prices, which are particularly systemically significant, are most affected by such hazards. As climate change intensifies, the frequency, magnitude and persistence of these inflationary pressures are likely to increase. Recent projections indicate that as soon as 2035, increases in average temperatures could contribute on average 0.92-3.23 percentage points annually to food inflation and 0.32-1.18 percentage points annually to headline inflation globally (see Figure S1). These increases could represent more than half of the 2% inflation target of most central banks in advanced economies that conduct monetary policy under inflation-targeting regimes. In the absence of countervailing forces, this could result in inflation targets being missed for significant periods of time.

Figure S1. Pressure on headline and food inflation rates due to higher average temperatures



Note: SSP 585 is a high-emissions scenario. Source: Kotz et al. (2024)

Additional supply-side risks stem from other climate-related physical hazards such as nature loss, and interconnected challenges, including disorderly transition policies and geoeconomic fragmentation. These factors might boost costs further, compounding inflationary pressures. Taken together, these crises could drive a 'Great Reversal' of the favourable supply-side developments that prevailed during the 'Great Moderation', a period of macroeconomic stability from the 1980s until 2008, in which inflation-targeting frameworks became widely adopted. During the Great Moderation, positive supply-side developments played an important role in anchoring inflation expectations and aligning inflation with central banks' targets; these developments included increased global trade integration and a significant expansion of the effective global pool of labour. In contrast, the emergence of severe and persistent supply-side headwinds would make it considerably more challenging to meet price stability targets.

Challenges and trade-offs for monetary policy

When a negative supply shock is transitory, leaving only a temporary imprint on headline inflation, the standard response is to 'look through' the shock. This entails maintaining – or even loosening – the monetary stance to protect output and avoid undershooting the inflation target once the shock subsides. However, if a series of negative supply shocks leads to sustained above-target inflation, FIT frameworks used by most major central banks will ultimately compel them to tighten monetary policy. For instance, the bout of inflation that followed the COVID-19 pandemic and the war in Ukraine was eventually met with monetary tightening once policymakers judged these shocks to be sufficiently persistent, with second-round effects and risks of de-anchored inflation expectations.

The welfare costs of sustained and aggressive tightening in response to persistent climate-related inflationary pressures, however, could be significant. Contracting monetary policy under these circumstances risks amplifying the negative impacts of supply shocks on economic output, financial stability, fiscal space, income inequality and progress towards a green transition, undermining the conditions needed for long-term price stability. Excessive tightening could also have lasting adverse effects on investment, reducing productive capacity and exacerbating trade-offs between medium- and long-term price stability.

A series of persistent negative supply shocks would thus present a new conundrum for central banks: the expected policy reaction could exacerbate sacrifice ratios (the loss in output or employment incurred for the central bank to reduce inflation by 1%), intensify macroeconomic vulnerabilities and delay the transition to carbon neutrality.

From 'flexible' to 'adaptive' inflation targeting

To avoid exacerbating the damage caused by climate-related supply shocks, monetary policymakers will have to consider, define and eventually adopt more adaptive monetary frameworks that clarify the importance of longer-term and climate-related supply conditions. Building on existing discussions, proposals and frameworks that revisit key features of FIT, we propose an 'adaptive inflation-targeting' (adaptive-IT) framework, summarised in Table S1. This framework enables the explicit accommodation of higher inflation over longer horizons when supply conditions are systematically pushing up costs, giving central banks the latitude to exercise patience and appropriate discretion before resorting to monetary tightening. Importantly, such a framework can also provide central banks and their fiscal counterparts with greater policy space to bolster supply-side resilience, facilitating a more coordinated response to supply shocks.

Such a shift must be communicated to economic agents and financial markets with clarity, precision and adequate timing. Maintaining credibility and managing expectations are paramount for inflation-targeting central banks. Therefore, any changes to monetary frameworks must not be perceived as an ad hoc accommodation or abandonment of previous commitments. Instead, the adoption of adaptive-IT should be framed as a response to new macroeconomic conditions in which the parameters guiding the definition of the appropriate monetary policy stance have shifted. Hence, adaptive-IT should be introduced in times of relative stability, when inflation is at or near the 2% target. Implementing such changes amid rising inflationary pressures could undermine central bank credibility and risk de-anchoring inflation expectations, particularly in emerging market and developing economies (EMDEs).

Table S1. Key differences between flexible and adaptive inflation targeting

Framework	Target	Horizon	Toolkit
Flexible inflation targeting	Usually a point target (typically 2%), sometimes with small accommodation bands	Medium term, typically two years	Policy rate, collateral policy and post-Global Financial Crisis unconventional monetary policies, all focused on managing aggregate demand
Adaptive inflation targeting	(a) Point target of same 2%, but with bigger accommodation bands (b) Explicitly targeting a range around 2% (c) A higher point target (3%) with smaller accommodation bands	Same as FIT, with a longer horizon (three or more years) when supply-side disruptions are pervasive	Same as FIT, with additional targeted instruments focused on supply-side resilience, macroprudential policy that adequately prices climate risk, and forecasting featuring climate and supply-side risks

Source: Authors

1. Introduction

Climate change, environmental degradation and the green transition all can have inflationary and disinflationary effects, which will become increasingly relevant to central banks' price stability mandates. Such effects will materialise to differing degrees depending on transition pathways and may have increasingly important implications for central banks' monetary policy stances and, more fundamentally, their monetary frameworks. To maintain their credibility and ensure they adopt the appropriate policy stance, inflation-targeting central banks must develop a deep understanding of these new inflationary risks, adjust their frameworks accordingly and clearly communicate these changes.

As of late 2024, inflation has returned close to target around much of the globe. Inflationary risks are on the rise once again, however. Many of these risks lie on the supply side of the economy and many are related to climate change. Such forces could trigger a reversal of the favourable supply-side conditions that prevailed during the 'Great Moderation' from the 1980s to 2008. In the late 20th and early 21st centuries, a wave of positive supply-side shocks – including the integration of China, India, and the countries of the former Soviet Union into the global economy – facilitated the job of inflation-targeting central bankers. Now, climate change and interconnected crises, including nature loss, disorderly transitions [1] and geoeconomic fragmentation, could cause a 'Great Reversal' of these favourable conditions.

Existing flexible inflation-targeting (FIT) frameworks allow monetary policymakers to 'look through' transitory supply shocks. However, if these shocks become sufficiently persistent to risk second-round effects and a de-anchoring of inflation expectations, monetary policy tightening then becomes the standard recommended policy response. Yet this response could conflict with other central bank and governmental priorities, such as advancing the green transition and ensuring long-term macroeconomic stability. Therefore, the FIT framework may require adaptation for an era of supply-side shocks and greater instability.

Purpose and structure of this report

This report reviews existing literature on climate change and price stability, considers the risk posed by more persistent climate-related inflationary pressure and explores the trade-offs, challenges and implications for monetary policy. It proposes a shift from FIT (see Box 1.1) to adaptive inflation targeting (adaptive-IT). This would prepare central banks to navigate supply-side headwinds while enabling fiscal policymakers to take a proactive role in preventing and mitigating negative supply shocks.

Section 2 provides an overview of the relevant pressures, their transmission channels and the existing empirical evidence on how the physical impacts of climate change affect inflation.

Section 3 outlines why climate change and interconnected crises could become a source of persistent inflationary pressures by compounding negative supply shocks.

Section 4 examines the challenges and trade-offs that more severe, frequent and persistent negative supply shocks would create for monetary policy.

Section 5 proposes a shift to adaptive-IT to better address the challenges of an era of new supply-side headwinds.

[1] We will cover the (dis)inflationary potential of green transition pathways in more detail in a further policy report.

Box 1.1. A primer on the FIT regime

Inflation targeting was first adopted by the Reserve Bank of New Zealand in 1989, quickly followed by Canada, the United Kingdom, Sweden and Australia (Hammond, 2012). It gradually became the dominant model of central banking and remains so today. This box summarises the key features of FIT frameworks, termed 'flexible', as it allows some accommodation of short-term shocks (Bernanke et al., 1999).

Mandate: A mandate specifying price stability as the primary objective of the central bank is enshrined in law, although this is often not the only objective. Financial stability was added to the mandates of many central banks following the Global Financial Crisis, and secondary objectives to support government economic priorities are also common.

Independence: Inflation-targeting central banks have 'operational' or 'instrument' independence, meaning that they decide how to meet their target. In some cases, central banks also have a degree of 'goal independence', as they set their own inflation target. However, in many cases, the target is set partly or entirely by government or elected representatives.

Targets: A specific inflation target is established, either a point or a range. The most common point target is 2%, as measured by the consumer price index (CPI), although ranges or accommodation bands that permit deviations from the central target are relatively common. Advanced economy central banks mostly have a target of 2% or, in some cases, between 1% and 3%.

Horizons: Central banks tend to adopt a medium-term policy horizon, which is generally understood to be approximately two years. This explicitly allows short-term deviations from target, although where central banks are actively seeking to lower inflation and gain credibility, they may adopt shorter-term horizons.

Forecasts and models: Central banks publish inflation forecasts, usually on a quarterly basis, to set out their expectations for the path of inflation. While forecasting frameworks evolve over time and differ between central banks, it is common for central banks to use a central 'workhorse' model, supported by a suite of models and surveys. Svensson (2009: 1) refers to FIT as "forecast targeting".

Committees: Monetary policy decisions are taken by a committee that meets on a semi-regular basis, usually somewhere between eight and 12 times a year. Committees are generally composed of senior central bank staff and external appointees. Decisions are often taken by majority vote, although consensus decision-making is often sought.

Decision-making: Adjustments to the policy rate are forward-looking and based on inflation forecasts produced by analytical and technical assessments. These decisions consider a range of macroeconomic indicators and analyses, including 'gap analysis' to assess the cyclical position of the economy relative to its equilibrium.

Accountability: It is common to have some form of accountability mechanism, such as parliamentary hearings or open letters between senior central bank leadership and elected officials. Central banks are also ultimately considered to be accountable to the public, with which they communicate through their publications and engagement fora.

Communication: Communications strategies, which mainly revolve around the publication of monetary policy reports and the minutes of monetary policy committee meetings, are central features of inflation-targeting frameworks. The degree of consent/dissent on the committee may or may not be published.

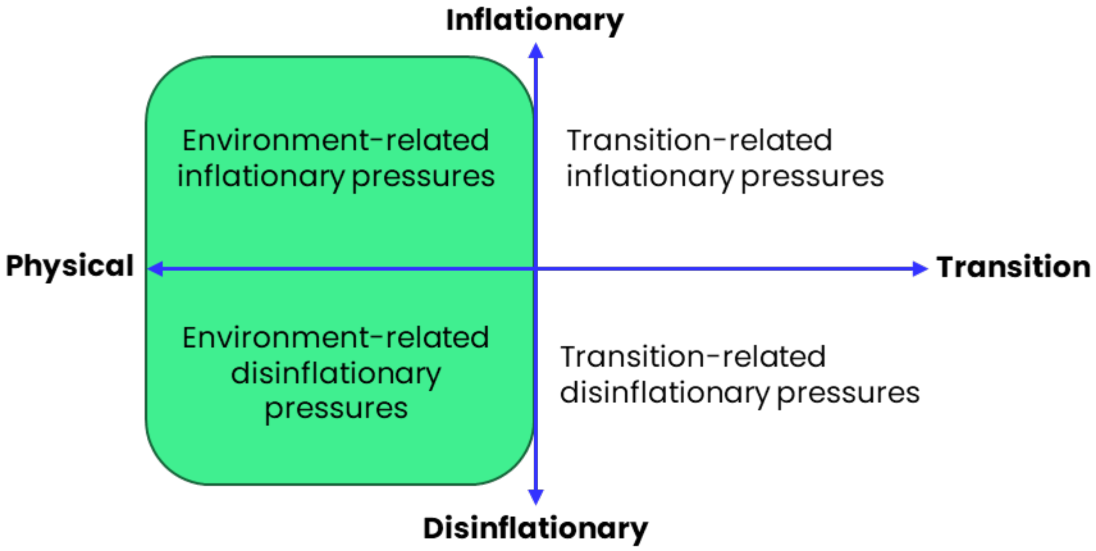
2. How climate change affects inflation

(Dis)inflationary pressures can stem from both the physical impacts of climate change and the transition to a net-zero economy. This section focuses on the physical impacts of climate change, which can affect economic activity – and, consequently, prices – through both supply and demand channels. On the supply side, climate change can damage physical capital and infrastructure, disrupt supply chains, reduce labour productivity and drive the migration of workers. These impacts primarily constrain productive capacity, generating inflationary pressures. Conversely, on the demand side, reductions in wealth and income can suppress aggregate demand, creating disinflationary effects. Tighter access to financing can further amplify both supply-side disruptions and demand-side contractions. Empirical evidence indicates that physical hazards frequently generate short-term inflationary pressures, with particularly pronounced effects on food prices.

A typology of (dis)inflationary pressures

In March 2022, Isabel Schnabel, a member of the European Central Bank's Executive Board, coined the terms 'climateflation', 'fossilflation' and 'greenflation' to describe how climate change, fossil fuels and the green transition can generate inflationary pressures (Schnabel, 2022). Building on Schnabel's initial typology, we propose conceptualising environment-related price pressures on two dimensions: i) whether they stem primarily from physical impacts of climate change, which are the central focus of this report, or from the transition to a more sustainable economy; and ii) whether these pressures are inflationary or disinflationary. This yields four categories, as shown in Figure 2.1.

Figure 2.1. (Dis)inflationary pressures in the context of physical and transition impacts



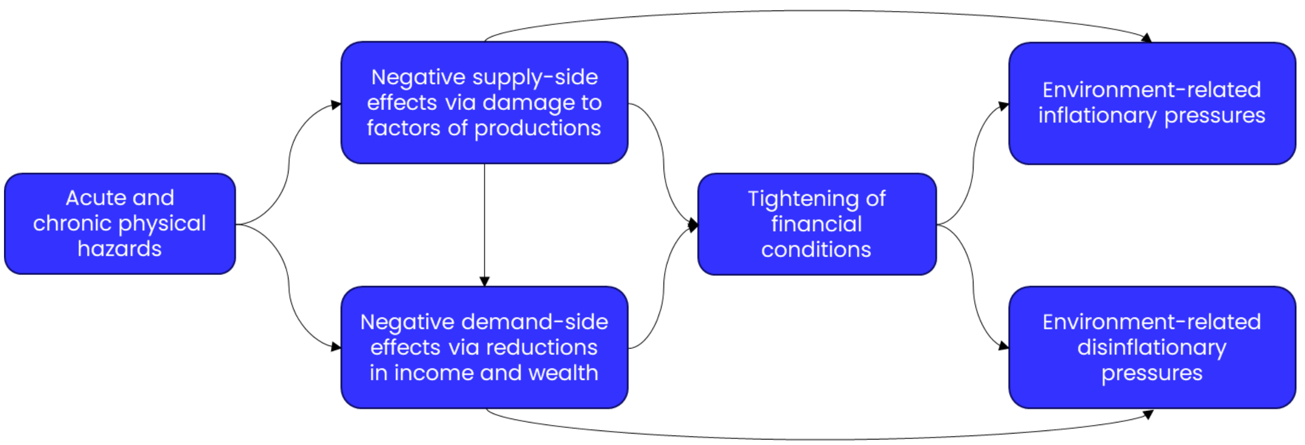
Source: Authors

Environment-related inflationary pressures arise from the physical impacts of climate change, which manifest as either chronic or acute physical hazards. These pressures include the effects of extreme weather events on land, capital and infrastructure, which can decrease agricultural and industrial outputs, driving up prices. Conversely, the physical destruction caused by climate change can exert disinflationary pressures by destroying assets, leading to reduced income and wealth, which in turn damps consumption and investment (Angeli et al., 2022; Drudi et al., 2021; NGFS, 2024a).

Transition-related inflationary pressures could emerge from policies such as carbon taxes and surges in green investment. Increased demand for renewable energy infrastructure, which is more capital-intensive because of significant upfront costs, will accelerate investment needs. Temporary inflationary pressures may also arise from challenges such as energy intermittency and storage during the transition, depending on its speed and orderliness. However, the successful and widespread deployment of renewable energy capacity could ultimately contribute to disinflationary effects and is essential to achieving long-term price stability (Allen et al., 2023; Heemskerk et al., 2022; Melodia and Karlsson, 2022).

The extent and nature of these pressures will vary from country to country, depending on their transition pathways and country-specific factors, such as income levels and vulnerability to physical hazards. This report focuses primarily on environment-related (dis)inflationary pressures (represented by the green-shaded left-hand side of Figure 2.1), as these are already influencing headline inflation and will do so increasingly as planetary boundaries are breached further. The remainder of this section provides an overview of the relevant transmission channels, summarised in Figure 2.2.

Figure 2.2. How climate change produces (dis)inflationary pressures



Source: Authors

Supply-side channels

The supply side of the economy encompasses the standard factors of production, including capital, labour and total factor productivity, which encompasses elements such as technology, infrastructure, supply chains and financing conditions (NGFS, 2024a). The physical impacts of climate change influence prices through their effects on these factors of production. Supply-side effects are mostly negative and, therefore, present inflationary risks. While positive effects on production with disinflationary forces are possible, they are likely to be very limited, localised and temporary, particularly as climate change intensifies.

The type of physical risk, its severity and the economic context in which it takes place are crucial in shaping the supply-side impacts. Acute hazards such as hurricanes, and chronic impacts such as rising sea levels, can cause widespread damage to the productive capacity of entire regions. Even limited damage to specific production processes can generate broader inflationary pressures by affecting systemically important sectors (Van't Klooster and Weber, 2024). For instance, droughts can negatively impact agriculture, electricity generation and semi-conductor production, all of which have ripple effects across the economy.

The impact of climate change on water levels, in the form of drought or excessive rainfall, can also affect inflation by disrupting supply-chain infrastructure, such as critical waterways and ports (Leslie, 2022). For example, low water levels in Germany's River Rhine disrupt industrial production by limiting the transport of coal, crude oil, coke and chemical products essential to upstream production processes (Ademmer et al., 2020). Similarly, drought-induced low water levels in the Panama Canal have significantly disrupted shipping traffic in 2024, exemplifying the type of supply-chain disruption likely to increase due to climate change (UNCTAD, 2024).

The movement and productivity of workers can also be affected by the physical impacts of climate change. For example, changes in temperature and rainfall have already caused large migrations in Sub-Saharan Africa and South America (Marchiori et al., 2012; Thiede et al., 2016). Wildfires and hurricanes have led to long-term displacements in countries including Australia and the US (NGFS, 2024a). Furthermore, temperatures above a certain threshold lower labour productivity and lead to reduced work hours (Zhang et al., 2018; Somanathan et al., 2021). The higher the initial temperature level, the larger the reduction in productivity for a unit increase in temperature (Burke et al., 2015).

Lastly, damage to physical assets can affect the banking and financial sector through market risk losses on equity portfolios and credit risk losses from non-performing loans. For example, the higher frequency of extreme weather events has produced significant losses for the insurance sector and alarmed the reinsurance industry (Swiss Re, 2024). In many regions, insurance costs have risen sharply or, in some cases, become unavailable. Significant capital losses can reduce investment, insurance coverage and bank lending, disrupting production for firms that rely on short-term credit and reducing long-term potential output if firms cannot access financing to upgrade technology and hire new workers. In addition, banks may face higher funding costs, which they may pass onto firms, as a result of increased deposit withdrawals and default risks (Levieuge, 2009).

Demand-side channels

On the demand side, the physical impacts of climate change can influence prices by negatively affecting household and firm wealth and income levels, undermining consumer and business confidence, and impairing the availability of credit and insurance. These effects are predominantly negative (as with supply-side impacts), implying disinflationary effects (unlike supply-side impacts). Negative demand effects can also result from negative supply effects, as inflationary pressures from damage to productive capacity can reduce real incomes and generate recessionary trends that lower aggregate demand. However, fiscal responses may increase demand, as governments invest in reconstruction efforts and/or expand spending to address the immediate needs of affected populations.

The destruction of residential real estate directly reduces household wealth, which can curb consumption. Even where properties are not destroyed, housing prices in affected areas may fall for several reasons. First, surrounding destruction may negatively impact the neighbourhood. Second, hazards can increase perceived risk of future disasters, leading to price penalties in affected areas (McCoy and Walsh, 2018; Bin and Landry, 2013; Ortega and Taspinar, 2018). Third, in hazard-prone areas such as flood zones, rising insurance premiums or the withdrawal of insurance coverage can drastically reduce house prices, especially where banks are no longer willing to provide mortgage loans.

The materialisation of physical hazards can also weaken firms' balance sheets by impairing productive assets and capital, leading to reduced business investment and the loss of jobs. For example, hurricanes in Florida have negatively affected short-run employment (Belasen and Polacheck, 2008), while hurricanes in other parts of the US (Groen and Polivka, 2008) and

Puerto Rico (Barattieri et al., 2023) have caused declines in labour-force participation and employment rates. Moreover, climate-driven migration can destroy agglomeration economies, further stifling growth (NGFS, 2024a).

As natural disasters reduce wealth and income levels, generating greater uncertainty and undermining consumer and business confidence, perceptions of risk increase. Firms may then scale back or delay planned investments, while households may save more as they consume less, exacerbating negative growth effects. For example, spending patterns following Hurricane Matthew in 2016 and Hurricane Sandy in 2012 show sharp declines in post-disaster spending, with no subsequent recovery to compensate for earlier shortfalls. Hurricane Sandy's exceptional size resulted in larger and more persistent aggregate impacts (Aladangady et al., 2017).

As with supply-side effects, the banking and financial sector amplifies demand-side impacts of physical hazards. For instance, the withdrawal or unaffordability of insurance amplifies downward pressures on consumption and investment. Physical hazards can also erode the value of borrowers' collateral. Consequently, borrowers may only be able to secure smaller loans or face higher interest rates (NGFS, 2024a).

At the government level, the fiscal response required for reconstruction, coupled with spending on the green transition, may lead to reduced government spending in other parts of the economy. In certain EMDEs, large climate impacts can also increase sovereign debt risk and create a 'diabolic doom loop', wherein declining sovereign creditworthiness strains the banking sector, raising the likelihood of bank bailouts that further degrade the sovereign's creditworthiness (Brunnermeier et al., 2016). More widely, natural disasters in EMDEs can significantly deter foreign investment (Ferriani et al., 2023).

Empirical evidence: short-term inflationary pressures

The net effects of physical hazards on inflation depend on which supply and demand channels are activated and most pronounced. A growing body of empirical literature examines these effects, with mixed findings. However, there is relatively consistent evidence of short-term inflationary pressures, as hazards negatively affect the supply side of the economy upon impact. In the medium term, disinflationary effects are also frequently observed. Here we focus on five key factors, covering impacts on both headline inflation and food inflation: type of physical hazard, intensity of the hazard, season in which the hazard occurs, income level of the affected country, and other economic and institutional factors. Food inflation warrants more attention than other sub-indices given that climate change disproportionately affects agriculture (Yusifzada, 2024) and food prices are systemically significant (Weber et al., 2024) as they have considerable predictive power for headline inflation (McCracken and Khánh Ngân, 2023) and play an outsized role in shaping inflation expectations (Bonciani et al., 2024).[2]

Type of physical hazard
Table 2.1 provides a synthesis of the evidence across different types of physical hazard. Where effects differ across other factors, such as country income level, further detail is provided in subsequent sections.

[2] Furthermore, food constitutes a higher proportion of lower-income countries' and households' consumption baskets, meaning that environment-related (dis)inflationary pressures could have highly unequal distributional effects (Barmes and Schröder Bosch, 2024).

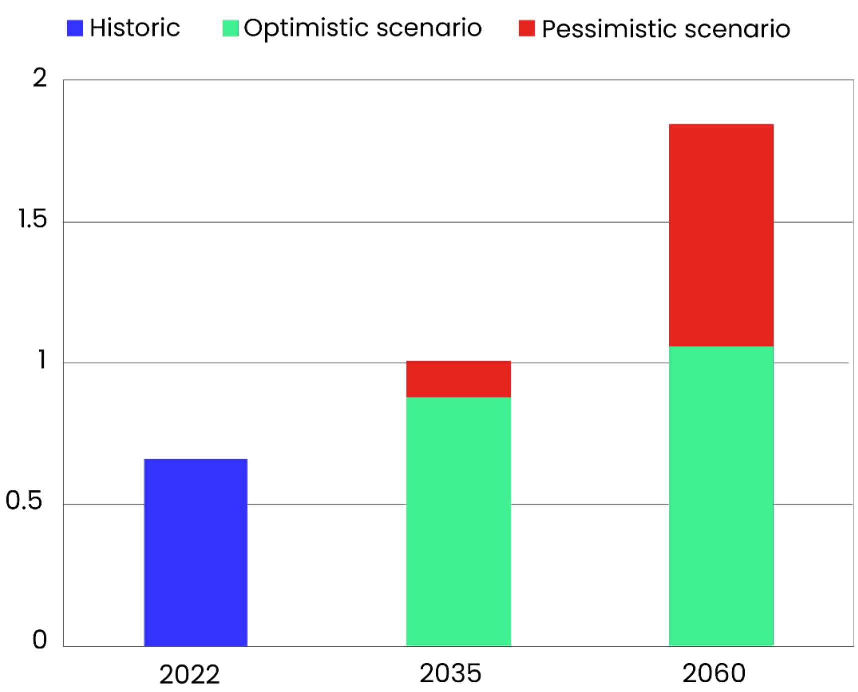
Table 2.1. A review of the evidence on the (dis)inflationary effects of different types of hazard

Type of hazard	Impacts on headline inflation	Impacts on food inflation
Temperature shocks	Temperature shocks and variability tend to cause short-term inflationary effects (Kotz et al., 2024: Mukherjee and Ouattara, 2021; Iliyasu et al., 2023; Ouattara et al., 2024). However, findings across studies are not always consistent and effects differ in magnitude, persistence and occasionally direction, depending on the sign of the temperature shock (Kabundi et al., 2022), time of year (Ciccarelli et al., 2023) and region (Kabundi et al. 2022; Cevik and Jalles, 2023). Kotz et al. (2024) find that the extreme heat in the summer of 2022 caused a cumulative annual impact of 0.34 percentage point on headline inflation in Europe. They project that by 2035, increases in average temperatures could contribute, on average, between 0.32 and 1.18 percentage points per year to headline inflation globally (see Figure 3.2).	Temperature shocks have strong inflationary effects on the food component of the CPI (Faccia et al. 2021, Kotz et al. 2024, Yusifzada, 2024; Lucidi et al., 2024; Iliyasu et al., 2023), particularly unprocessed foods (Ciccarelli et al., 2023). Findings across studies are not always consistent and effects differ depending on the sign of the shock (Ciccarelli et al., 2023), the time of year (ibid.) and region (Kabundi et al. 2022, Kotz et al. 2024, Faccia et al., 2021; Cevik and Jalles, 2023). Kotz et al. (2024) find that the extreme heat in the summer of 2022 caused a cumulative annual impact of 0.67 percentage point on food inflation in Europe, which could rise to 1.8 percentage points by 2060 (see Figure 2.3). They also project that by 2035, increases in average temperatures could contribute, on average, 0.92-3.23 percentage points per year to food inflation (see Figure 3.2).
Precipitation shocks	Precipitation shocks can generate inflationary effects, generally of a lower magnitude and persistence than temperature shocks (Kabundi et al., 2022; Kotz et al., 2024; Ouattara et al., 2024). There is also limited evidence of disinflationary effects (Kabundi et al., 2022; Bremus et al., 2020).	Precipitation shocks have non-linear effects on food prices. While they can generate downward pressures on agricultural prices (Yusifzada, 2024), extreme precipitation shocks tend to cause short-term food inflation (Moessner, 2022; Faccia, 2021; Bremus et al., 2020; Jirophat et al., 2022).
Droughts	There is considerable evidence of droughts having positive (Kabundi et al., 2022; Parker, 2018a) and persistent (Parker, 2018a) impacts on inflation, up to 3 percentage points (Kabundi et al., 2022), although there is also evidence of negligible (Kamber et al., 2013) or even negative (Bremus et al., 2020; Cevik and Jalles, 2023) effects in certain cases. Kabundi et al. (2022: 4) find that "droughts tend to have the highest overall positive impact on inflation" with moderate or severe droughts contributing up to 3 percentage points to headline inflation within a year.	Studies consistently find significant upward effects of droughts on food inflation, with the inflationary impact reaching up to 10 percentage points (Kabundi et al., 2022). Even in cases where studies find no or negative effects on headline inflation, effects on food inflation are always positive (Bremus et al., 2020; Cevik and Jalles, 2023; Kamber et al., 2013). Kabundi et al. (2022) find that droughts cause a 5 percentage-point increase in food inflation upon impact, rising close to 10 percentage points in the third quarter after impact.
Floods	Evidence on the (dis)inflationary effects of floods is limited and mixed. Parker (2018a) estimates an immediate inflationary impact of 0.38 percentage point, while Heinen et al. (2019) find	Analysis of the effect of floods on food inflation is even more sparse than headline inflation. Extreme positive precipitation shocks can generate flooding, which suggests that short-term

	immediate positive impacts of up to 0.6 percentage point, but Kabundi et al. (2022) find that severe floods lower inflation by up to 2 percentage points a year after the shock.	inflationary pressures are likely, as outlined above. However, Kabundi et al. (2022) find mostly deflationary effects, in line with their results on headline inflation.
Storms	Storms tend to generate short-term inflationary pressures (Heinen et al., 2019) and disinflationary effects in the longer run (Kabundi et al., 2022; Parker, 2018a). The effects differ depending on various factors, discussed below, such as intensity of the storm and country income level (Cevik and Jalles, 2023).	Storms tend to generate short-term food price rises that dissipate relatively quickly (Kabundi et al., 2022; Parker, 2018a; Bao et al., 2023; Heinen et al., 2019). Focusing on China, Bao et al. (2023) find that the inflationary effects are significantly larger for fresh foods/perishable goods than non-perishables.
El Niños and indices of severe weather events and climate variables	El Niño periods have consistently generated short-term inflationary pressures for most countries (Cashin et al., 2017; Nam, 2021; Ventosa-Santaulària et al., 2024). When looking at indices that encompass various severe weather events and/or climate shocks, there is evidence of both short-term inflationary (Beirne et al., 2024; Crofils et al., 2024) and disinflationary (Kim et al., 2022) effects.	El Niño periods have historically generated increases in global food commodity prices, though effects differ by region and crop type (Adolfsen and Lappe, 2023). Inflationary effects associated with severe weather indices are particularly pronounced for food products (Beirne et al., 2024), to the extent that effects on headline inflation are positively correlated with the share of food in countries' CPI baskets (Cashin et al., 2017).

Source: Authors

Figure 2.3. Estimated impact of summer heat on food price inflation (percentage points)



Source: Kuik et al. (2023), based on Kotz et al. (2023). Note: Kuik et al. (2023) provide the following explanatory note regarding the method used to produce this figure: "Estimated with a global panel regression approach, using monthly prices and high-resolution climate data. Cumulative deviation of food inflation from baseline after 12 months due to extreme June/July/August temperatures are shown. The chart is based on combining elasticities of a 1°C increase in temperatures with results from 21 global climate models. Projected temperatures of a 2022-like summer (i.e., in the upper tail of the temperature distribution) in future climates are retrieved from climate model results under an optimistic ("below 2C by 2100", RCP2.6) and a pessimistic ("hot house world", RCB8.5) emissions scenario. Impacts could be reduced through ambitious adaptation to warmer climates."

Intensity of the hazard
The inflationary effects of physical hazards tend to be non-linear, meaning that they become disproportionately more pronounced as the severity and persistence of the hazard increase (Parker, 2018a; Kotz et al., 2024; Faccia et al., 2021; Kabundi et al., 2022; Jirophat et al., 2022). Parker (2018a: 42) explains that this is in line with findings on the effects of natural disasters on economic activity, which show that "larger disasters exceed an economy's capacity to remain resilient". This suggests that as climate change increases the severity, persistence and frequency of physical hazards, environment-related bouts of inflationary pressure are equally likely to intensify in magnitude and frequency. Chavleishvilli and Moench's (2023: 35) findings suggest that "the increased frequency and severity of natural disasters imply substantially more mass on lower growth and higher inflation outcomes and considerably higher macroeconomic volatility", especially under a 'current policies' scenario in which emissions continue to rise. Furthermore, Kotz et al. (2024: 4) find that "under a best-case emission scenario, exogenous pressures on inflation are only marginally larger in 2060 than in 2035, but a worst-case emission scenario would cause pressures on food inflation exceeding 4 [percentage points per year] across large parts of the world."

Season in which the hazard occurs
Climate-related shocks have non-linear and, at times, opposing effects on prices in different seasons of the year. In the summer months, positive temperature shocks tend to have positive effects on inflation, which is higher in hotter months and regions (Kotz et al., 2024; Faccia et al., 2021; Ciccarelli et al., 2023). According to Kotz et al. (2024), temperature shocks in the Northern mid-latitudes can have upward effects on food inflation that are almost twice as large in summer as in winter, whereas effects are relatively constant across seasons in the low latitudes. The same shocks in colder months of the year tend to have disinflationary effects, particularly at the highest latitudes (Kotz et al., 2024), probably as a result of improved agricultural production and decreased energy demand (Lucidi et al., 2024). There has been little investigation into the differential seasonal effects of other types of environment-related shocks, although El Niño periods have been shown to have asymmetric effects on crops across different regions and growing seasons (Adolfsen and Lappe, 2023).

Income level of the affected country
Developing countries are most frequently and severely touched by the physical impacts of climate change and are likely to bear the brunt of their economic impacts. There is considerable evidence of the inflationary effects of climate change and associated natural disasters generally being stronger and more persistent in developing countries (Faccia et al., 2021; Mukherjee and Ouattara, 2021). Disproportionate impacts on food prices, combined with developing countries' larger share of food in CPI baskets, is likely to be responsible for this pattern (Cashin et al., 2017; Faccia et al., 2021). However, this is not necessarily a straightforward or consistent relationship, as there is evidence of varied effects depending on other factors (covered in this section), such as the type of shock in question (Kabundi et al., 2022; Cevik and Jalles., 2023). Furthermore, studies that look at international dynamics point in a different direction altogether, showing that economic activity and inflation in advanced economies may be more exposed to shocks to global commodity prices (including those related to weather disruptions) (De Winne and Peersman, 2021; Parker, 2018b).

Other economic and institutional factors
Other factors that may influence how prices are affected by climate shocks include the position of an economy in the business cycle and its level of public debt (Cevik and Jalles, 2023; they use public debt as a proxy for fiscal space). Inflationary effects may also vary depending on the credibility of the monetary policy regime: countries with inflation-targeting central banks and well-anchored inflation expectations seem to experience lower and less persistent inflationary effects from climate shocks. For example, Kabundi et al. (2022) find that in inflation-targeting countries, droughts and floods have little impact on inflation, whereas in non-inflation-targeting regimes, droughts produce a 3 percentage-point jump in inflation and floods generate a gradual 1 percentage-point increase in inflation in the second year. This report, however, will consider how inflation-targeting regimes may face new challenges to their credibility as physical and transition risks materialise at greater speed and magnitude.

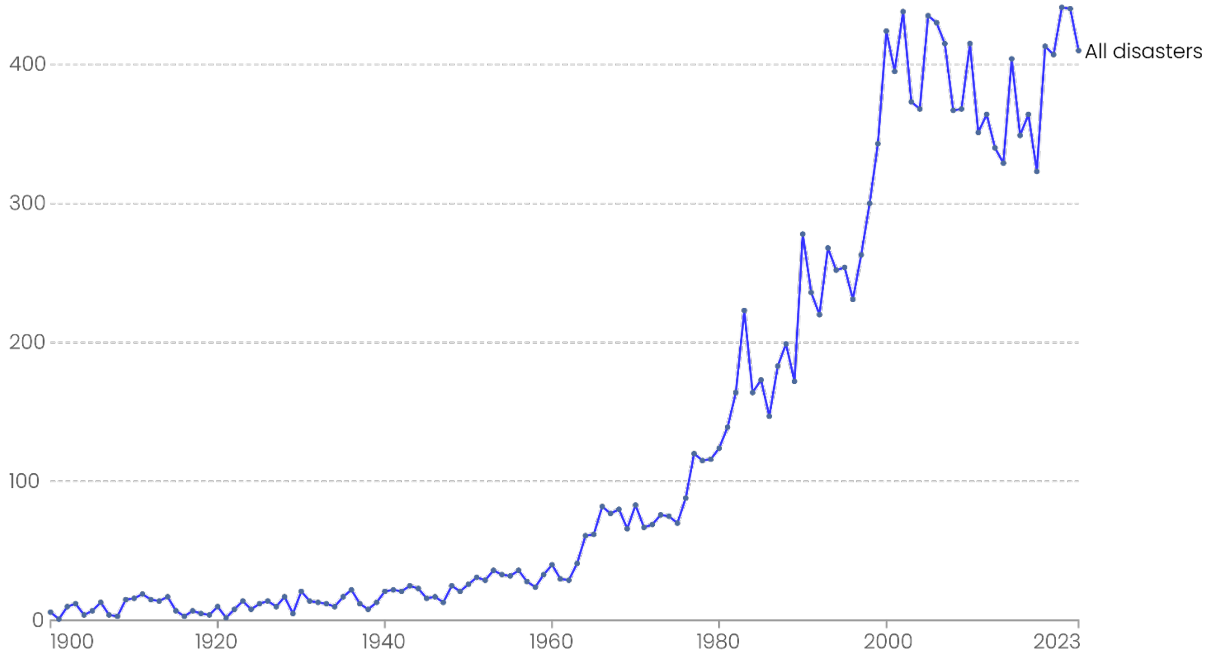
3. Risk of persistent inflationary pressures

The physical impacts of climate change typically manifest as negative supply shocks upon impact, increasing prices while decreasing output. This section explains that as climate change intensifies, physical hazards may become a more persistent source of inflationary supply shocks for several reasons. First, the empirical evidence shows that more severe physical hazards have disproportionately greater inflationary impacts. Second, the inflationary effects of physical hazards are likely to be transmitted internationally in ways that most existing studies on climate change and inflation do not capture. Third, these effects may be compounded by additional intersecting sources of supply-side disruption in the polycrisis, such as nature loss, disorderly transition policies and geoeconomic fragmentation.

Frequency and severity of physical hazards

The empirical literature to date on the price impacts of physical hazards offers limited insights, as the frequency and severity of such hazards are increasing and will continue to escalate as climate change intensifies. Figure 3.1 shows a quadrupling in the number of natural disaster events recorded since 1980. While some of this increase can be attributed to improved reporting (Ritchie and Rosado, 2024), it is clear that weather and climate extremes are becoming more severe and frequent, with climate change a significant driver of that trend (IPCC, 2021).

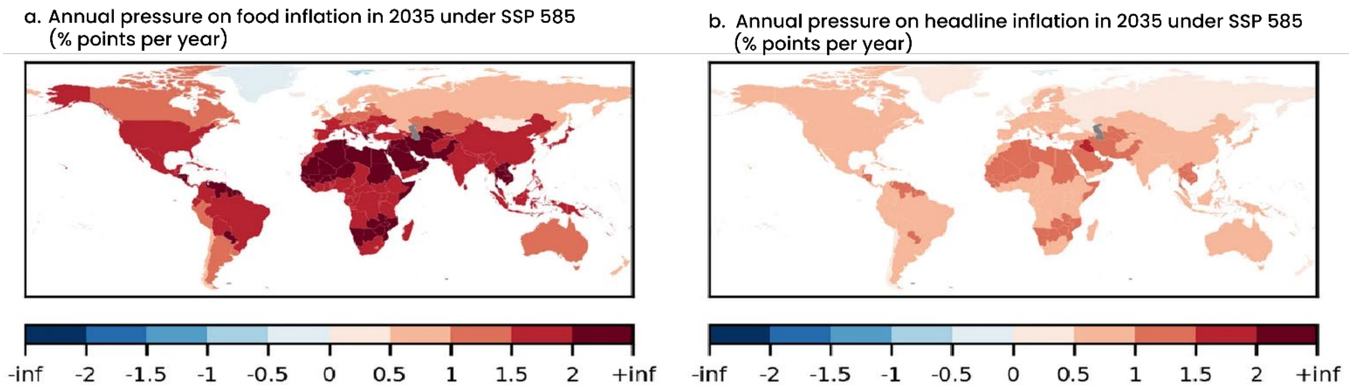
Figure 3.1. Number of recorded natural disasters, 1900 to 2023



Notes: The number of global reported natural disaster events in any given year. This largely reflects increases in data reporting, and should not be used to assess the total number of events. Data includes disasters recorded up to April 2024. Source: Ritchie and Rosado (2024) from data source: EM-DAT, CRED/UCLouvain (2024)

As outlined above, the empirical literature indicates that the inflationary effects of the physical impacts of climate change are likely to become substantially more pronounced and persistent as climate change intensifies, given the positive relationship between the severity of extreme weather events and the resulting inflationary impacts (Parker, 2018a; Kotz et al., 2024; Faccia et al., 2021; Kabundi et al., 2022; Jirophat et al., 2022). This implies that the effects of severe physical impacts will increasingly overwhelm economies' supply-side resilience. This is also in line with Chavleishvilli and Moench's (2023) findings, which imply higher inflation outcomes under high-emission scenarios. Focusing specifically on temperature, Kotz et al. (2024) project that globally, by 2035, higher average temperatures could contribute on average 0.92-3.23 percentage points per year to food inflation and 0.32-1.18 percentage points per year to headline inflation (see Figure 3.2). At the upper end, these increases would correspond to well over half of the 2% inflation target of most central banks in advanced economies that conduct monetary policy under an IT regime. In the absence of countervailing forces, this alone could result in inflation targets being missed for significant periods of time.

Figure 3.2. Pressure on headline and food inflation rates due to higher average temperatures



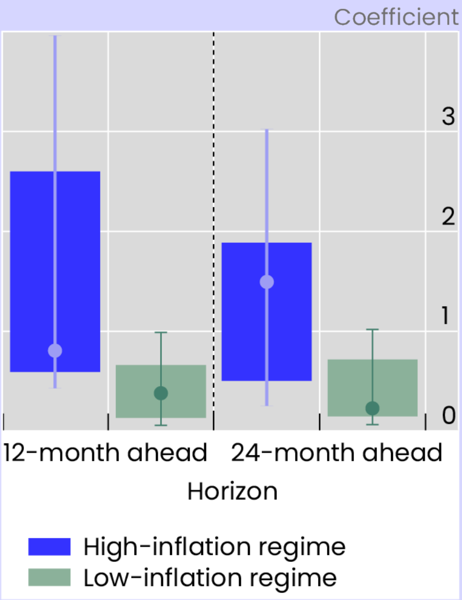
Note: SSP 585 is a high-emission scenario. Source: Kotz et al. (2024)

Compounding physical hazards with inflationary consequences could contribute to a transition from a low-inflation regime to a high-inflation regime, in which inflation becomes more self-sustaining by way of its embeddedness in domestic wage- and price-setting dynamics. As discussed in Box 3.1, the Bank for International Settlements (BIS) shows that sector-specific relative price changes pass through to core inflation to a greater extent in high-inflation regimes (Borio et al., 2023). Whether or not climate change itself is responsible for the transition to a high-inflation regime, the inflationary effects of physical hazards would become more pronounced and disequilibrating in such a context.

Box 3.1. The two-regime view of inflation

In its 2022 Annual Economic Report, the BIS introduced the 'two-regime view of inflation', further developed by Borio et al. (2023). In a low-inflation regime, self-equilibrating properties mean that "sector-specific price changes move together hardly at all, and they leave only a temporary imprint on the inflation rate" (Borio, 2022: 3), whereas a high-inflation regime entails self-disequilibrating properties and greater pass-through of relative sector-specific price shocks to core inflation (see Figure 3.3, taken from Borio et al., 2023).

Figure 3.3. Distribution of pass-through coefficients



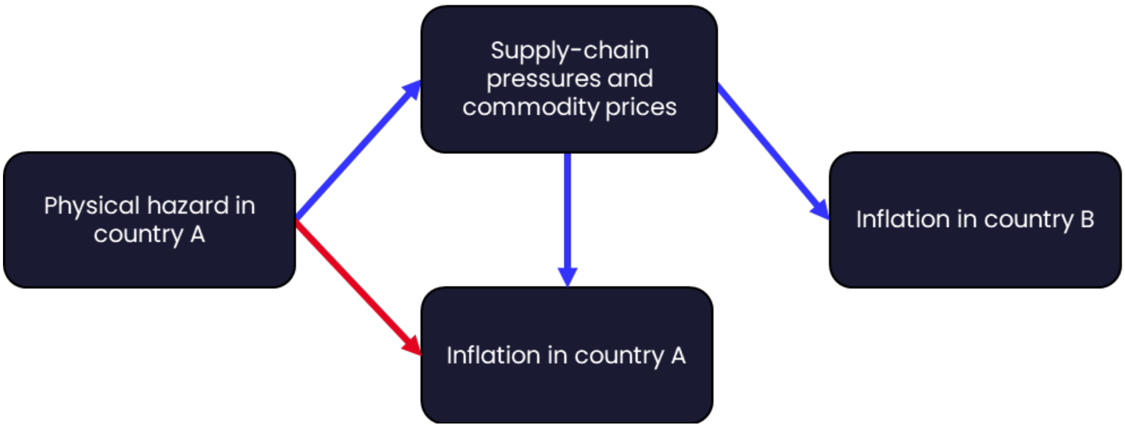
Transitions from low- to high-inflation regimes can be driven by structural forces, cyclical forces and inflation itself. While the BIS highlights globalisation, demographics, technology and political priorities as obvious examples of such forces, the physical impacts of climate change are potentially another type of structural force that could contribute to such a transition. The inflationary effects of hazards would then also become more pronounced and disequilibrating should a high-inflation regime take hold, regardless of what triggered the transition.

According to Borio et al. (2023), in a low-inflation environment, price dynamics provide the central bank with significant flexibility. Fluctuations in the inflation rate are mainly driven by sector-specific relative price changes that have only temporary effects. As a result, wages and prices are less likely to push each other upwards. This flexibility allows the central bank to be more tolerant of moderate, or even persistent, deviations from strict inflation targets. In contrast, "once inflation becomes entrenched, monetary policy's task becomes much harder" (ibid.: 27) and the costs of bringing inflation under control rise.

International transmission of inflationary pressures

Given that most existing studies focus solely on the domestic impacts of domestic climate-related shocks, they preclude analysis of how economies will be increasingly affected by physical hazards elsewhere in the world. In Figure 3.4, the red arrow representing the direct effects of a physical hazard in country A on inflation in country A is the focus of most of the literature, whereas the blue arrows representing the indirect effects through international channels are neglected. In our interconnected global economy, inflation has become an increasingly global phenomenon (Ciccarelli and Mojon, 2010), and the growth of global value chains plays an important role in explaining this increasing influence of global factors on domestic inflation (Auer et al., 2017). Combining such perspectives with key conclusions from the literature on climate change and inflation reveals additional potential sources of inflationary pressure related to physical hazards.

Figure 3.4. How a physical hazard can cause inflationary effects through international channels



Source: Authors

On the one hand, the international integration of production processes makes economies more resilient to localised shocks, as diversified supply chains and substitution strategies can mute the economic effects of adverse supply shocks (including inflationary effects). On the other hand, international economic integration also leaves economies more exposed to disruptions around the globe through supply-chain dislocations, commodity markets and financial contagion. For example, volatility in international food prices, which are particularly vulnerable to physical hazards, can significantly affect domestic inflation. A 10% increase in global food prices is estimated to cause inflation in advanced economies to rise by around half a percentage point after a year (Furceri et al., 2016). Furthermore, global food commodity price fluctuations account for almost 30% of consumer price instability in the euro area (Peersman, 2022). Looking specifically at weather-related disruptions, De Winne and Peersman (2021) find that such hazards reduce harvests and lead to higher agricultural commodity prices globally, lowering real gross domestic product (GDP) while driving up domestic prices.

The inflationary effects of climate-related disruptions to supply chains are also under-studied, yet could become an important source of price instability, given the growing role of supply-chain pressures in driving inflation (Diaz et al., 2024). Cevik and Gwon (2024: 5) argue that "the impact of weather shocks on supply chains and inflation dynamics is likely to become more pronounced with accelerating climate change that tends to have heterogeneous effects across and within countries". A 1-standard-deviation increase in global shipping costs already contributes 0.15 percentage point to headline inflation over 12 months, with bigger effects in countries with a higher share of imported final consumption (Carrière-Swallow et al., 2023). More broadly, a 1-standard-deviation shock to supply-chain pressures generates an increase in headline inflation amounting to about 2 percentage points in China, 2.1 percentage points in the UK and 3.8 percentage points in the US over a 24-month period (Cevik and Gwon, 2024).

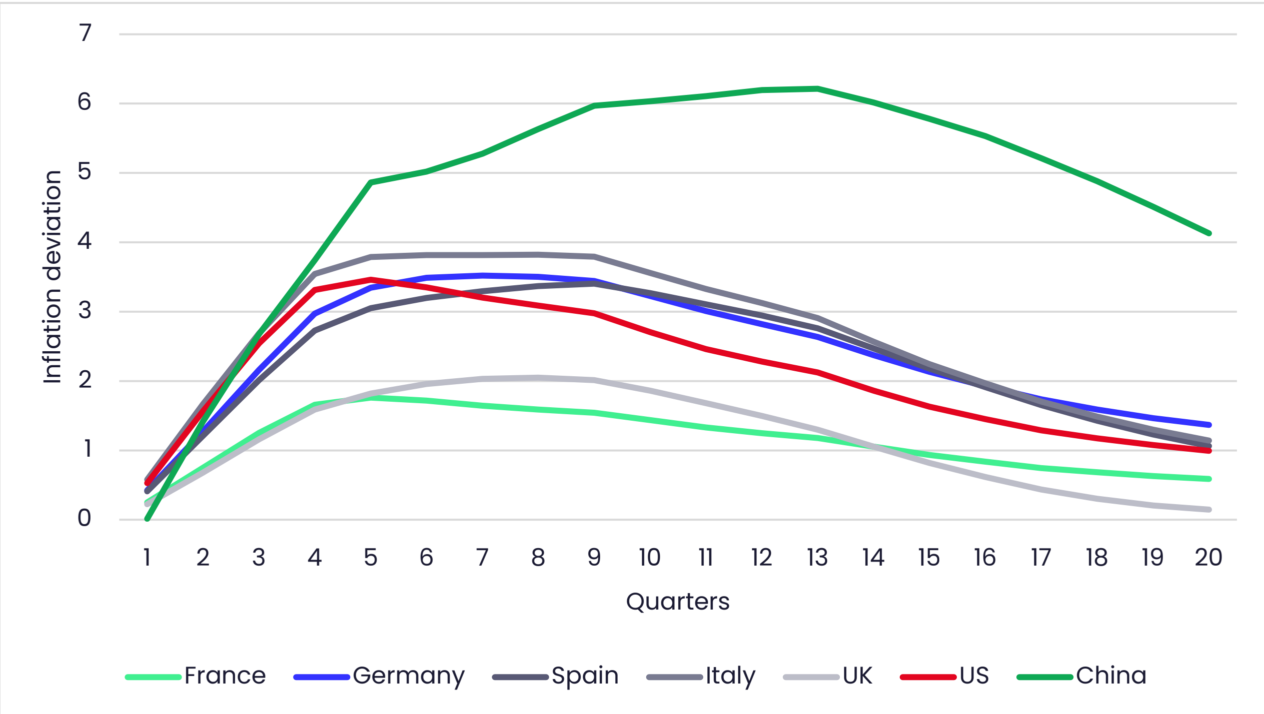
Nature loss and disorderly transition scenarios

Climate change is only one feature of a wider 'global polycrisis' that presents many additional supply-side inflationary risks that intersect with, and could amplify, environment-related inflationary pressures. The global polycrisis can be defined as a "causal entanglement of crises in multiple global systems that significantly degrade humanity's prospects" (Lawrence et al., 2022: 2). Tooze (2022) and the World Economic Forum (2023) popularised the concept – originally coined by complexity theorists Morin and Kern (1999) – to describe multiple disparate shocks that are interacting in such a way that "the whole is even more overwhelming than the sum of its parts" (Tooze, 2022). As evidenced by the high rates of inflation following the COVID-19 pandemic and the war in Ukraine, there are many interconnected sources of supply shocks – such as nature loss, disorderly transition policies and geoeconomic fragmentation – that can produce bouts of inflation.

While this report is focused on climate change, the wider degradation and collapse of natural ecosystems – which exacerbate and are exacerbated by climate change – also have macrofinancial implications. Marsden et al. (2024) highlight that the crossing of 'ecosystem tipping points' increases economies' vulnerability to climate-related natural disasters while also increasing the severity of natural disasters. As natural ecosystems degrade and potentially cross tipping points, we are likely to witness greater spikes in the prices of commodities, more severe natural disasters and reduced natural and economic resilience to such disasters (Almeida et al., 2024; Marsden et al., 2024). Climate change and nature loss are so closely intertwined that it is arguably conceptually flawed to separate 'climate'-related risks from wider 'nature'- or 'environment'-related risks (Kedward et al., 2022). Yet, the bulk of the literature on the economic and financial consequences of environmental degradation focuses exclusively on climate change, missing a potentially major source of supply shocks.

Furthermore, certain transition policies, such as sudden environmental regulations or disorderly carbon taxation, could prove an additional source of negative supply shocks. As highlighted in Figure 2.1, the green transition can be a source of both inflationary and disinflationary sources.[3] In disorderly transition scenarios, negative supply shocks are a particularly probable source of inflationary pressure, which could be compounded by positive demand shocks resulting from the scaling up of green investment. Allen et al. (2023) model the inflationary effects of an abrupt and unanticipated increase (of almost US$400 per ton of CO_2 equivalent) in the price of carbon, showing that this scenario could cause considerable overshooting of inflation targets (see Figure 3.5). In the long term, however, given the destabilising properties of the physical impacts of climate change and the price volatility of fossil fuels, a green transition is a necessary precondition for price stability (Heemskerk et al., 2022; Melodia and Karlsson, 2022).

Figure 3.5. Estimates of the inflationary effects of disorderly carbon taxation (% point deviation from baseline year-over-year growth rate)



Source: Authors, based on Allen et al. (2023)

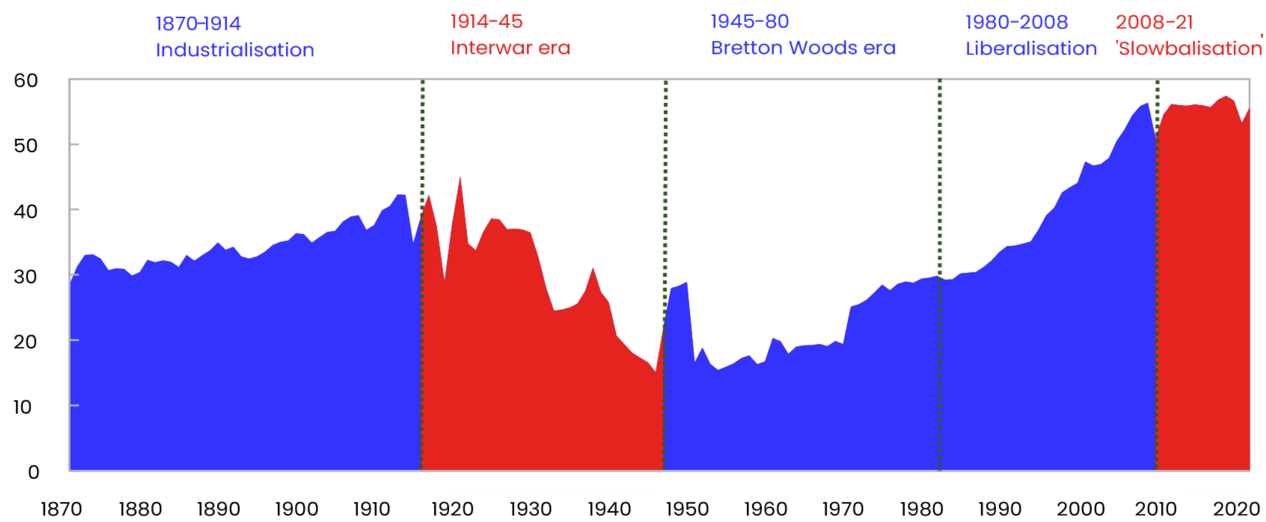
[3] Allen et al. (2023) provide an overview of all the different supply and demand shocks that could generate such pressures.

Geopolitical risks compounding inflationary risks

Climate change and wider environmental degradation can also increase the likelihood of price instability through their effect on other potential drivers of such instability, such as geopolitical risk. Trade openness has plateaued (as illustrated in Figure 3.6), geopolitical tensions are on the rise, and companies and governments are increasingly exploring on-shoring, near-shoring or friend-shoring policies (Aiyer et al., 2023). The outcome of the recent US election raises the likelihood of ever more protectionist measures and higher tariffs. That could see US inflation climbing by over 4 percentage points more than it would have done by 2026 (McKibbin et al., 2020). Moreover, it is also likely to affect inflation in the rest of the world, especially if China and Europe take retaliatory measures. This is the latest political development pointing in the direction of further geoeconomic fragmentation.

Like the physical impacts of climate change and environmental degradation, geopolitical risks can cause negative supply shocks through the destruction of human and physical capital, disruptions to international trade and supply chains, and spikes in commodity prices. Iacoviello et al. (2024: 3) provide evidence of a positive relationship between geopolitical risks, inflation uncertainty and significant inflation increases in advanced and emerging economies, noting that "supply-side factors emerge as particularly significant, as evidenced by the concurrent rise in inflation and decline in real economic activity in the face of geopolitical tensions". They find that the Russian invasion of Ukraine in 2022 added about 1.2 percentage points to world inflation and, more generally, that a 1-standard-deviation shock in geopolitical risk increases inflation by about 2 percentage points (ibid).

Figure 3.6. Trade openness, 1870-2021 (sum of exports and imports, percentage of GDP)



Source: Aiyer et al. (2023)

Regardless of the extent to which particular geopolitical tensions are or are not exacerbated by climate instability, the economic costs of such phenomena will stack up and potentially amplify each other. Geoeconomic fragmentation could further exacerbate the inflationary pressures resulting from environment- and transition-induced negative supply shocks through multiple channels. For example, diversifying supply chains and importing substitutes for goods affected by physical hazards could become more challenging and expensive, and access to the transition-critical materials needed to scale up renewable energy infrastructure could be jeopardised (Nobletz et al., 2024). Aiyer et al. (2023: 5) also warn that geoeconomic fragmentation is "likely to complicate multilateral cooperation in critical areas such as climate change mitigation and pandemic preparedness".

If sufficiently severe and persistent, negative supply shocks arising from these interconnected phenomena would effectively represent a reversal in the favourable supply-side conditions that previously underpinned price stability. During the Great Moderation – a period of trade liberalisation characterised by sustained macroeconomic stability from the 1980s up to the Global Financial Crisis of 2008 – a series of positive structural macroeconomic supply shocks, such as China and the integration of the countries of the former Soviet Union into the global economy, generated persistent disinflationary forces that facilitated a low-inflation regime.[4] It was during this period that inflation-targeting frameworks were widely adopted and established their credibility. To the extent that the relative stability of natural ecosystems and geopolitical relations during the Great Moderation made central banks' job easier, a 'Great Reversal' of such conditions would make their job considerably more challenging.

[4] While there is debate as to the extent to which price stability in the 1990s was the result of supply-side forces or institutional reforms and policy action conducted by independent inflation-targeting central banks, there is no doubt that the former aided the job of the latter.

4. Challenges for monetary analysis and policy

A scenario of compounding negative supply shocks that generate persistent inflationary pressures would be particularly challenging for monetary policymakers. If supply shocks caused persistent inflationary pressures to the extent that inflation expectations risked becoming de-anchored and triggering a transition to a high-inflation regime, existing monetary frameworks and best practice would require central banks to tighten monetary policy (Bandera et al., 2023). However, as we see in this section, tightening in response to negative supply shocks involves many trade-offs in relation to economic output, financial stability, fiscal space, income equality, the green transition and longer-term macroeconomic stability.

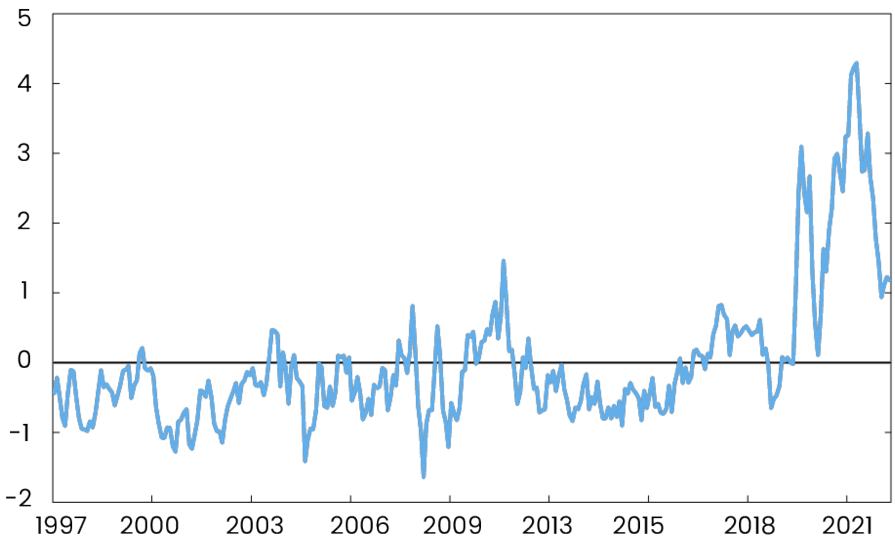
Anticipating and identifying negative supply shocks

While the short-term impacts of physical hazards on inflation and output are generally consistent with the characteristics of negative supply shocks, disinflationary pressures often follow the initial spike in prices. This suggests a damping of demand that eventually counterbalances the inflationary effects of contracting supply, which explains why some authors highlight the relevance of negative overall demand shocks (Ciccarelli et al., 2023; Ciccarelli and Marotta, 2024; Lucidi et al., 2024). In practice, neatly disentangling and identifying macroeconomic shocks is not a straightforward exercise. As noted by Faccia et al. (2021) in their study of the impacts of temperature shocks on inflation, short-term inflationary effects followed by disinflationary effects are consistent with the notion of a 'Keynesian supply shock', in which a negative supply shock causes recessionary conditions that lower output and employment (Guerrieri et al., 2020). Therefore, identified aggregate negative demand shocks, including those associated with the physical impacts of climate change, may in fact partly be "sectoral supply shocks with aggregate demand consequences" (Cesa-Bianchi and Ferrero, 2021: 3).

Efforts are underway to incorporate climate factors, including their supply-side effects, into macroeconomic modelling. Highlighting that "climate-related shocks and trends are still generally absent from the canonical models used by central banks for their policy analysis and forecasting", Boneva and Ferrucci (2022: 1) propose integrating climate modules into central banks' workhorse models and the suite of time-series models they use to complement them. Furthermore, the Network for Greening the Financial System (NGFS) recently published a guide for central banks on incorporating physical and transition impacts into macroeconomic modelling, which includes a discussion on modelling the supply side of the economy (NGFS, 2024b).

More broadly, determining an appropriate response to negative (or Keynesian) supply shocks – regardless of their source – requires analytical tools to identify when such shocks are occurring. The development of such tools has accelerated in the wake of post-COVID 19 supply-chain disruptions and the war in Ukraine. For example, the Federal Reserve Bank of New York (n.d.) developed the Global Supply Chain Pressure Index, which "integrates transportation cost data and manufacturing indicators to provide a gauge of global supply chain conditions" (see Figure 4.1), while the Federal Reserve Bank of San Francisco developed a novel method to decompose supply- and demand-driven inflation (Shapiro, 2024). The Bernanke Review of the Bank of England's forecasting framework also recommended that greater resources be devoted to supply-side analysis (Bernanke, 2024).

Figure 4.1. Global Supply Chain Pressure Index, standard deviations from average value

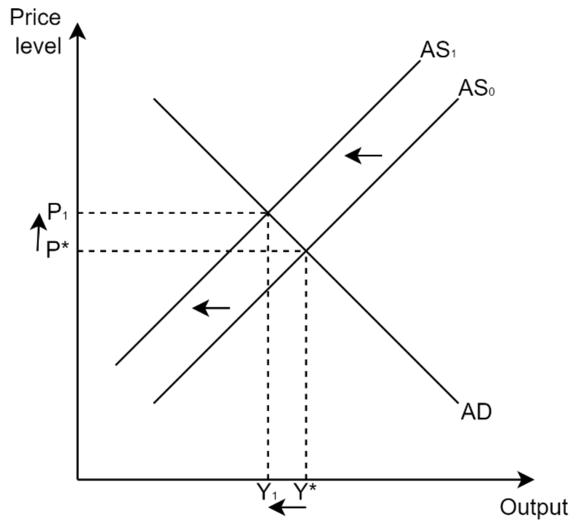


Source: Akinci et al. (2023)

How inflation targeters respond to negative supply shocks

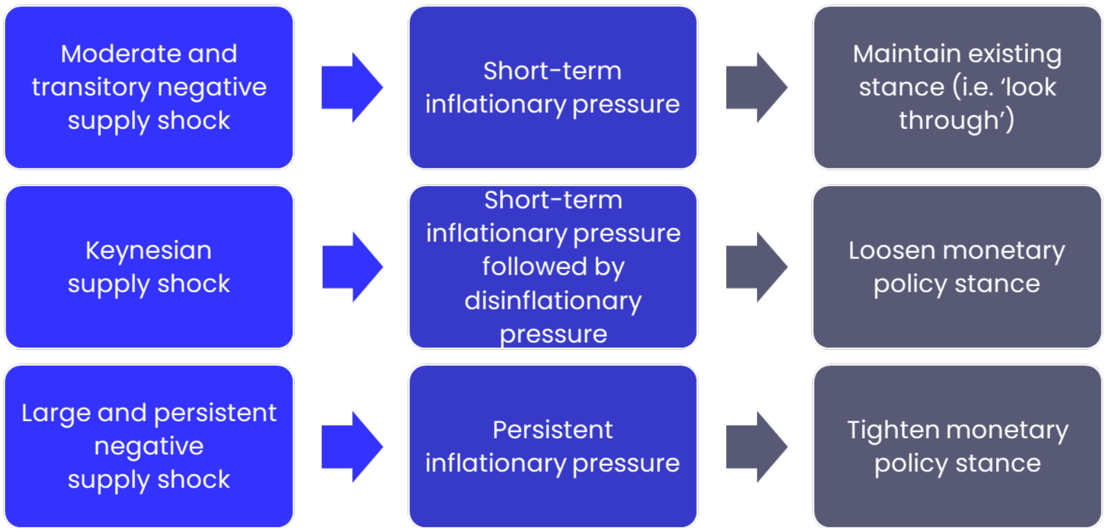
Inflation-targeting monetary policymakers are required to address inflationary pressures, regardless of their source (see Box 1.1 for a primer to the inflation-targeting regime). They consider many factors when responding to negative supply shocks, such as "the nature and duration of the shock, the strength of second-round effects and the impact of the shock on real incomes as well as efficiency considerations" (Bandera et al., 2023: 28). Figure 4.2 illustrates the impacts of a negative supply shock on output and the price level in a simple aggregate supply-aggregate demand (AS-AD) framework. If the shock is deemed to be short-lived, central bankers are likely to 'look through' the inflationary pressure, that is, refrain from tightening monetary policy. Loosening monetary policy may even be a preferred response if the supply shock is of a 'Keynesian' nature and leads to a reduction in aggregate demand, a common pattern following climate-related shocks. Klomp (2020) finds that monetary authorities often reduce interest rates following earthquakes, prioritising output stabilisation. In contrast, if the shock is large and persistent, monetary policymakers are more likely to tighten monetary policy to prevent a de-anchoring of inflation expectations and minimise the risk of transitioning to a high-inflation regime. The different responses to different types of adverse supply shock are summarised in Figure 4.3.

Figure 4.2. A negative supply shock in an AS-AD framework



Source: Authors

Figure 4.3. Typical monetary responses to different types of negative supply shock



Source: Authors

Trade-offs when responding to negative supply shocks

Negative supply shocks present a classic inflation-output trade-off, as well as trade-offs in relation to financial stability, fiscal space, income equality and the green transition. If monetary policymakers deem it necessary to tighten monetary policy in a sustained and/or more aggressive way in response to compounding supply shocks, there could be substantial negative repercussions for these other policy areas, many of which feature to varying degrees in central bank mandates and remits (Dikau and Volz, 2021).

Economic output

Central bank mandates typically require monetary policymakers to support, or at least consider, their policy decisions' effects on economic output. Yet when inflation rises above target, monetary policy is intended to bring it back down, precisely by damping aggregate demand, thereby slowing economic growth. In cases of pure positive demand shocks, where both output and inflation are rising, there is no trade-off between inflation and output stabilisation. In contrast, adverse supply shocks present a well-established output trade-off for central banks, as inflation and output move in opposite directions. Differing analyses and views on how to navigate this trade-off are a source of disagreement on monetary policy committees, especially where central banks have dual mandates (Madeira et al., 2023). 'Doves' seek to minimise the negative output gap via an accommodative monetary stance, whereas 'hawks' seek to minimise deviation from the inflation target via a tighter stance. The more persistent and repeated the negative supply shocks, the more this trade-off intensifies, with the option of 'looking through' becoming less tenable.[5]

Financial stability

As monetary tightening is intended to impact economic output by constricting financial conditions, policymakers must also navigate a financial stability trade-off when doing so. Like the tension between price stability and output, the existence and magnitude of a trade-off between price stability and financial stability depend on the source of inflation. If inflation is demand-driven, strong cash flows provide borrowers with protection against rate hikes, such that the risk of financial instability being generated by monetary tightening is minimal. On the

[5] For an investigation of the effects of monetary policy's response to supply shocks specifically in EMDEs, see Ocampo and Ojeda-Joya (2022).

contrary, negative supply shocks heighten instability risks, and the more inflation is supply-driven, the stronger the negative financial response becomes (Boissay et al., 2023). This is unique to negative supply shocks because of the downward pressure they exert on output and, therefore, on borrowers' cash flows. Rate hikes then place further pressure on households and firms that are already under strain, thereby increasing credit default risk (ibid.). Consequently, there is a considerable risk that repeated monetary tightening in response to compounding supply shocks could feed financial stability risks. Lastly, tightening may also entail valuation losses that have an impact on the capital and liquidity positions of financial sector agents. As explored further in the next section, this financial stability trade-off highlights the need to better price climate risks and adapt prudential policy accordingly.

Fiscal space

Monetary tightening also places pressure on a country's fiscal position by increasing government debt-servicing costs. This is particularly problematic for EMDEs. The cycle of monetary policy tightening that followed the COVID-19 pandemic and the war in Ukraine resulted in record debt-servicing costs across low- and middle-income countries. In 2023, the World Bank deemed 60% of the lowest-income countries (defined as those eligible for International Development Association resources) to be in debt distress or at high risk of debt distress. Meanwhile, foreign debt totalled over US$ 3 trillion across low- and middle-income countries (World Bank, 2023). On top of the physical impacts of climate change constraining EMDEs' monetary policy space and affecting their borrowing costs (Beirne et al., 2021), monetary policy tightening in advanced economies exerts pressure on central banks in EMDEs to tighten their monetary policy stance to minimise capital flight and exchange-rate volatility (Löscher and Kaltenbrunner, 2023). The recent tightening of monetary policy, in addition to the high deficits and high levels of public debt following the Global Financial Crisis and COVID-19 outbreak, have resulted in a return to more contractionary fiscal rules. However, in this context of reduced fiscal space, too rapid a contraction of fiscal positions would be particularly problematic and damaging, given the high investment needs of a net zero transition in both advanced economies and EMDEs.

Income inequality

In addition to the inter-country inequality that monetary tightening can produce through its effects on fiscal policy, there is also a well-established risk of deepening intra-country inequality. The inflationary impacts of climate-related shocks are likely to be borne far more by low-income households in the first instance, due to these shocks' disproportionate effects on the food component of the CPI, which makes up a larger share of low-income households' consumption baskets compared with higher-income households (Barmes and Schröder Bosch, 2024). Interest rate increases seeking to tame these inflationary pressures can then have their own adverse distributional effects, as low-income households are likely to experience unemployment and income reductions as a result of the slowdown in economic activity that monetary policy tightening induces (Furceri et al., 2018). These effects would only deepen in a scenario of sustained tightening and would not be reversed in times of monetary easing, due to their asymmetrical nature (ibid.). Targeted fiscal transfers could address this problem, although, as discussed above, fiscal space would also be constrained in this scenario. This is a particular concern when linked to the political economy challenges observed in many countries, where sociopolitical discontent has led to instability and fragmentation of the political landscape, with the rise of populist movements that eventually impact institutional stability and, hence, the macroeconomy.

Green transition

Lastly, monetary policy also has diverse effects from sector to sector, with implications for the green transition. On the one hand, Altavilla et al. (2024: 29) find that the contractionary effect of monetary policy tightening is "milder for firms with low emissions and those that commit to decarbonization", as banks are beginning to factor carbon emissions into their lending decisions, charging a higher climate risk premium to carbon-intensive firms. On the other hand, meeting environmental goals requires a shift of investment towards green technologies that require far greater upfront capital expenditures than the carbon-intensive energy infrastructure they are intended to replace. This capital intensity means that green investment and the levelised cost of electricity generated by renewables are much more sensitive to the increases in the cost of capital resulting from interest rate hikes. Therefore, while low-emission firms are less affected by a tightening of monetary policy, renewable energy projects are extremely sensitive to such tightening (Martin et al., 2024; Schmidt et al., 2019). Furthermore, Aghion et al. (2024) show that green patents are also disproportionately impacted by tight financial conditions.

Monetary policy transmission channels

Negative supply shocks and subsequent monetary contractions also have implications for the transmission channels of monetary policy, potentially making monetary policy less effective in achieving price stability. Adverse supply shocks can impair aspects of all the typical transmission channels of monetary policy: interest rates, expectations, asset prices, credit supply and exchange rates. For example, a series of such shocks could reduce the sensitivity of aggregate demand to changes in interest rates. If shocks persistently bear down on consumers' disposable income, a bigger proportion of consumers' income is likely to be spent on non-discretionary goods (such as food and energy) that are more demand-inelastic and less sensitive to monetary policy. Aggregate demand would, therefore, become less sensitive to interest rate changes. Furthermore, if such shifts in spending patterns were sufficiently persistent, CPI basket weightings, which are usually adjusted on an annual basis, would also have to shift to reflect them (Laurentjoye, 2024). Such a change in CPI weightings could increase the risk of persistent inflationary pressures, as the prices of inelastic goods, such as food and energy, tend to be those that are most affected by supply shocks.

Furthermore, while monetary tools target the demand side of the economy, they have effects on the supply side that can exacerbate the inflationary effects of negative supply shocks. By increasing the cost of financing, monetary policy tightening can disrupt investment, particularly in capital-intensive sectors such as renewable energy (as discussed above), thereby decreasing long-term productive capacity, which may have already been affected by the negative supply shock. In studying the 'scarring effects' of negative supply shocks on output, Fornaro and Wolf (2023: 19-20) refer to a "supply-demand doom loop", as they find that monetary policy tightening can "end up deepening scarring effects and increasing inflation in the medium run". In line with these findings, Ma and Zimmerman (2023) estimate that a 100 basis-point tightening shock can lower output by 1% after five years due its negative effect on investment in innovation, while Guérin (2023) finds the same contractionary shock exerts a 1.5% percent decline in total factor productivity on a six-year horizon. Jordà et al. (2024) find persistent negative effects on productive capacity for at least 12 years.

These effects on both the demand- and supply-side transmission channels of monetary policy imply what may be the biggest trade-off of all for monetary policymakers when responding to negative supply shocks: the choice between short- to medium-term and longer-term price stability.

Box 4.1. What will happen to the 'natural rate of interest' (r*)?

The natural rate of interest (r*) refers to the real interest rate at which the supply of savings equals the demand for investment. In neoclassical theory and New Keynesian models, r* is associated with long-term equilibrium, where the economy operates at full potential output with stable inflation. This is a highly contested concept, as it relies on assumptions relating to the classical dichotomy, loanable funds, rational expectations, the exogeneity of shocks and the neutrality of monetary policy (Storm, 2021; Mongelli et al., 2024). Despite these debates, r* remains a central concept in monetary analysis, modelling and decision-making. Therefore, this box briefly explores how the dynamics discussed in this report could theoretically affect r* and, by extension, influence monetary policy decisions. These considerations should be placed within the broader context of forces affecting r*, such as fiscal and demographic trends (Benigno et al., 2024; Holston et al., 2017).

The potential impact of climate and transition-related factors on r* is complex, involving both upward and downward forces. On the one hand, the increased frequency and severity of acute and chronic physical hazards can constrain productivity growth and economic output, incentivise precautionary savings by households and firms, and increase demand for safe assets – all of which would exert downward pressure on r*. On the other hand, the green transition requires a significant increase in green capital spending and investment, exerting an upward force on r* (Mongelli et al., 2024; Drudi et al., 2021; Angeli et al., 2022).

Overall, climate change could, at least temporarily, lower r*, especially if higher demand for green investments is outweighed by growth-damping factors and risk-averse behaviours. If inflation-targeting central banks calibrate nominal policy rates based on current assumptions of the neutral rate plus expected inflation, while the 'true' neutral rate is lower than the present one, this misalignment could lead to an inadvertently contractionary policy stance. Furthermore, if inflation during the transition to net zero errs systematically above the 2% target, the standard reaction by the central bank will have to be to hike its policy rate even further to be in a safe, restrictive territory. Such a scenario could result in an overly contractionary policy stance that undermines long-term sustainability.

5. An adaptive inflation-targeting framework

The FIT framework that dominates central banking today may encounter significant challenges in sustained persistent inflationary pressures from increasingly severe, persistent and frequent supply shocks. Without an appropriate policy response, central banks risk losing credibility, either by repeatedly overshooting inflation targets and/or by causing excessive damage to long-term economic resilience through over-tightening. How can we retain the benefits of FIT while addressing these climate-related challenges? This section proposes a shift to adaptive inflation targeting (IT), designed to better manage unstable supply-side conditions. Adaptive-IT would mitigate the risks of monetary over-tightening in response to supply shocks, providing a better balance between medium-term price stability, secondary objectives and longer-term macroeconomic stability. To maintain credibility, central banks should adopt this framework in times of relative stability, when inflation is at or around target, and clearly communicate its rationale and benefits. The framework should be complemented by fiscal policy that plays a more proactive role in identifying, preventing and responding to negative supply shocks.

Key features of adaptive inflation targeting

Adaptive-IT retains the core principles of FIT while enabling monetary policymakers to adapt their approach when inflation is driven primarily by adverse supply conditions. For inflation stemming from demand shocks, the existing target, horizon and toolkit may be maintained. However, the adaptive-IT framework would allow central banks to exercise greater discretion and targeted policymaking when dealing with negative supply shocks, ensuring that they did not tighten monetary policy excessively in response to inflationary pressures originating on the supply side of the economy. This would allow central banks to preserve credibility in the face of supply-side headwinds, while minimising monetary policy's negative impacts on other policy objectives and on longer-term productive capacity. As summarised in Table 5.1, accommodation bands or a target range, a longer policy horizon and a broader toolkit with more instruments would all feature in an adaptive-IT framework.

This proposal has similarities to other recent innovations in the operation of inflation-targeting regimes. First, the idea of using additional instruments beyond the policy rate arose in the face of destabilising pressure from capital flows and credit in the wake of the Global Financial Crisis, with the need to fulfil the two objectives of price and financial stability. Agénor and Pereira da Silva (2019) conducted a review of the challenges inflation targeting has faced, including imperfect policy credibility, fiscal dominance, exchange-rate volatility and the fear of floating. The review was from the perspective of EMDEs, though it is also applicable to advanced economies. A key question emerged: how should central banks respond to expansionary shocks induced by capital flows, integrating financial stability considerations into the conduct of monetary policy? This analysis ended up proposing an integrated inflation-targeting (IIT) regime, an approach that treats monetary and macroprudential policies as complements rather than substitutes. Agénor and Pereira da Silva (2019) emphasised the need to calibrate monetary and macroprudential policies jointly and in a state-contingent manner, drawing policy lessons for preventing systemic financial crises such as the Global Financial Crisis. To counter persistent destabilising capital inflows, the IIT proposal suggests combining monetary policy rate action with complementary instruments such as macroprudential tools. This approach can be transposed to address climate-related risks by incorporating them into the calibration of both the ex-ante and ex-post policy stance, obtaining a monetary stance that calibrates policy rate action with macroprudential tightening.

Second, a separate discussion on the workings of IT emerged during the COVID-19 crisis, when central banks were undershooting their inflation target. Clarida (2020) proposed an average inflation-targeting (AIT) regime, in the context of similar discussions regarding a price level targeting (PLT) framework (Svensson, 2020; Adrian, 2021). The adoption of AIT, particularly by the US Federal Reserve, justified "patience" in maintaining accommodation for a longer period in the post-COVID-19 environment. Under AIT, central banks can achieve an average inflation rate over time, allowing periods of inflation above the target to compensate for previous periods below it. AIT was introduced in response to supply- and demand-side challenges that central banks faced, especially in the aftermath of the pandemic, which created persistent economic disruptions and low-inflation environments. AIT's 'averaging out' feature is particularly useful when the economy has experienced prolonged low inflation and near-zero interest rates, which was common following the Global Financial Crisis and exacerbated in the first instance by the COVID-19 shock. By shifting focus from year-to-year inflation to a multi-year horizon, AIT gives central banks more flexibility in responding to economic shocks without needing to immediately tighten policy when inflation rises slightly above target. This approach also allows central banks to focus on a robust economic recovery, as it implies a willingness to tolerate higher inflation temporarily if it helps to support full employment and stronger demand.

Table 5.1. Key differences between flexible and adaptive inflation targeting

Framework	Target	Horizon	Toolkit
Flexible inflation targeting	Usually a point target (typically 2%), sometimes with small accommodation bands	Medium term, typically two years	Policy rate, collateral policy and post-Global Financial Crisis unconventional monetary policies, all focused on managing aggregate demand
Adaptive inflation targeting	(a) Point target of same 2% but with bigger accommodation bands (b) Targeting explicitly a range around 2% (c) A higher point target[1] (3%) with smaller accommodation bands	Same as FIT, with a longer horizon (three or more years)[2] when supply-side disruptions are pervasive	Same as FIT, with additional targeted instruments focused on supply-side resilience, macroprudential policy that adequately prices climate risk, and forecasting frameworks featuring climate and supply-side risks

Notes: 1. For a discussion of a higher target for different reasons, see Blanchard (2022). 2. For a discussion of longer periods for convergence for different reasons (actual inflation below the 2% target), see the discussions at the US Federal Reserve and European Central Bank on AIT (Clarida, 2020)
Source: Authors

The adaptive-IT proposal combines and builds on features of both the IIT and AIT regimes. It attempts to provide a practical modus operandi, responding to the realisation of and growing concerns about the risk of intensified supply-side headwinds raised by senior central bankers, including Brainard (2022), Schnabel (2023), Maechler (2024) and Bénassy-Quéré (2024).[6] The remainder of this section provides further details on key features of an adaptive-IT framework.

Inflation target

Adaptive-IT frameworks could maintain existing targets (usually 2%) when there are no persistent supply-side disruptions.[7] However, an upward accommodation band (which tolerates an additional amount inflation) of as much as 2 percentage points should be formalised in the framework as a buffer when inflationary pressures are driven by supply shocks. Alternatively, adaptive inflation targeters could choose to shift fully to a range, such as 2–3.5% (Bloesch, 2022), or a higher point target, such as 3% (Blanchard, 2022), with a smaller accommodation band. In all these proposals, the risk of over-correction in times of price volatility would be addressed. We do not prescribe a one-size-fits-all approach, as the exact extent of the increase in the target, range or accommodation band may vary from jurisdiction to jurisdiction depending on several factors, such as the existing target and the threshold at which inflation becomes more salient to consumers and firms (Korenok et al., 2023). Discussions regarding a higher inflation target have been ongoing since the 2010s and must be revisited in response to recent inflationary episodes and the emerging risks discussed in this report. Such a discussion would benefit from being conducted collectively in the central banking community and prior to entering such a period of supply shocks.

Policy horizon

A complementary approach to introducing greater adaptability to supply-side conditions into monetary frameworks is to allow extensions to the monetary policy time horizon beyond the medium term (typically two years). This would provide additional scope for 'looking through' supply shocks and for considering the longer-term supply-side effects of monetary policies. The emerging evidence on the negative supply-side effects of monetary tightening challenges the traditional view of monetary policy being 'neutral' in the long run (Fornaro and Wolf, 2023; Ma and Zimmerman, 2023; Jordà et al., 2024), which supports the case for taking into account longer-term effects. If supply-side conditions are stable, meaning that any inflation is largely demand-driven, central banks could effectively apply their usual time horizon. However, if significant supply-side disruptions arise, a longer horizon (in other words, more 'patience') would minimise the risk of central banks tightening monetary policy excessively and thereby compounding damage to productive capacity. Existing FIT frameworks adopt a medium-term horizon to avoid over-corrections that unnecessarily harm economic output. Extending the horizon is an extension of this principle and has been advocated and put into practice by AIT (Clarida, 2020).

Data and analytical infrastructure

Allowing higher inflation when supply-side disruptions arise, institutionalised in the target and the horizon, requires sufficient data and analysis on the supply side of the economy.[8] This is a core feature of an adaptive-IT framework (or perhaps a prerequisite). Building on analytical developments discussed in Section 4, further work will be necessary for central banks to gain a fuller picture of their economy's supply chains, their points of vulnerability, the macrofinancial implications of different types of supply-side disruption, and the supply-side effects of monetary policies. Borrowing from prudential policy developments, a next step for central banks could be to engage in supply-chain stress tests. In the same way that financial policymakers developed stress tests of the financial system following the Global Financial Crisis to inform prudential policy, the development of supply-chain stress testing could inform monetary policy (as well as wider economic policy). Adaptive inflation-targeting central banks

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[6] Pisani-Ferry and Mahfouz (2023: 123) also raise concerns regarding a period of 'Great Volatility' during the transition and discuss implications for monetary policy.

[7] Shocks that are strictly demand-side are less relevant to discussions on the inflation target as, by definition, they do not cause monetary policy dilemmas.

[8] Dhingra (2023: 10) notes that the lack of data on prices along the stages of supply chains "poses considerable challenges for understanding inflation dynamics and calibrating to the optimal monetary policy stance".

could leverage their expertise to develop methodologies for system-wide supply-chain stress testing. Such exercises may require coordination with finance ministries, other government departments and the private sector.

Models and inflation forecasts
Improvements in the data and analytical infrastructure should inform the modelling that central banks rely on to forecast inflation under prevailing economic conditions and alternative scenarios. These models vary in complexity and purpose, ranging from structural macroeconomic models (for example, Dynamic Stochastic General Equilibrium or DSGE models) to time-series short-term models, as well as machine-learning artificial intelligence tools, financial models and sectoral models. Under FIT regimes, central banks set a policy interest rate path aimed at reaching the inflation target within a specified time horizon, while achieving a balance between stabilising inflation and minimising output volatility. The convergence process involves forward-looking decision-making based on inflation forecasts and other economic indicators, which is why FIT has been labelled 'inflation forecast targeting' (Svensson, 1997; Svensson, 2009). Central banks are increasingly integrating climate-related data and integrated assessment models into their suite of models and scenario analysis exercises, while also integrating climate modules into their workhorse models, to assess and manage the economic and financial risks associated with climate change (Boneva and Ferrucci, 2022; NGFS, 2024b). These models help central banks analyse the impact of physical and transition risks on the economy and financial system. The novel issue for adaptive-IT lies in assessing whether the policy reaction to persistent climate-related supply shocks would be sub-optimal, creating excessive output and employment losses, and to evaluate the welfare outcomes of a counterfactual scenario with a higher target and/or accommodation band.

Toolkit and instruments
Central banks operating adaptive-IT should also adapt their toolkits to better support supply-side resilience. For example, targeted refinancing schemes that support particular policy objectives, such as the green transition, can support the long-term productive capacity of economies and minimise the negative repercussions of monetary tightening.[9] As central banks shift their monetary frameworks when unwinding their balance sheets, there is likely to be a greater role for structural monetary policy operations, such as long-term refinancing facilities and structural securities portfolios, in managing liquidity in the system (Lez, 2024). This shift should provide greater space for such a targeted approach, favouring strategically important sectors of the economy, or at least protecting them from a potential tightening in the monetary stance. Of course, there are limits to which certain sectors, firms or households can be protected without undermining the wider tightening of the monetary stance. More proactive steering of credit via quantitative tools, such as portfolio quotas and restrictions, could also enter the toolkit to contribute to stabilising supply-side conditions (Kedward et al., 2023). Last, but not least, on the preventive side, it is important to properly price climate risk ex-ante, complementing the toolkit with macroprudential policy, jointly calibrated with monetary policy, to build supply-side resilience (Agénor and Pereira da Silva, 2019).

Communication
Under any IT regime, communication is key and can be as powerful as policy itself. Communication plays a role in anchoring expectations, reinforcing central bank credibility and supporting policy effectiveness, even when conventional tools are constrained. When new features are added to the framework, such as under IIT and AIT, communication on the policy stance can become challenging due to the need to convey financial vulnerabilities and systemic risks, and the subsequent reaction function of the central bank. Similarly, given the AIT framework's focus on dynamically adapting to supply-side conditions, communication on supply-side developments and their macrofinancial implications is critical to its effectiveness.

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[9] Debate is ongoing on the merits and risks of a more targeted approach to monetary policy, particularly with regard to supporting a green transition. The question of how monetary policy could support a green transition (see, for example, NGFS, 2021) has typically been treated as separate to the question of how climate change and a green transition may affect the appropriate policy stance, which is the primary subject of this report. However, the distinction between these two questions becomes blurred when considering the role of a green transition in achieving longer-term macroeconomic stability.

Furthermore, central banks would have to communicate very clearly any adjustments in their targets and horizons, as well as the conditions under which such adjustments would apply. The main risks to manage in shifting to a new framework surround potential damage to central bank credibility and the de-anchoring of inflation expectations. Careful justification, framing and communication of such changes would be necessary to mitigate these risks.

The policy mix under adaptive inflation targeting

Another benefit of the adaptive-IT framework is that it leaves more room for fiscal policy to play a role in addressing the sources and impacts of negative supply shocks, as the framework avoids over-tightening monetary policy and further restricting fiscal space. The COVID-19 pandemic and war in Ukraine have also led governments to prioritise supply-side resilience. For example, the Biden administration required government agencies to engage in 100-day supply-chain reviews, established a supply-chain disruption task force and a council on supply-chain resilience, and oversaw the establishment of a Supply Chain Center in the Department for Commerce and a Freight Logistics Optimization Works programme at the Department for Transport. Building on such initiatives, the administration then sought to secure and bolster key supply chains through a series of legislative initiatives, including the Creating Helpful Incentives to Produce Semiconductors (CHIPS) and Science Act, the Inflation Reduction Act, and the Bipartisan Infrastructure Deal.

Should supply-shock prevention fail, fiscal interventions such as price caps and subsidies may then be effective in mitigating the effects, smoothing the path of inflation and preventing expectations from becoming de-anchored. Again, recent experience provides plentiful examples, as governments around the world have implemented fiscal measures to bring down headline inflation, minimise the pass-through of high commodity prices to core inflation, and make it easier for households and firms to weather the inflationary episode (Amaglobeli et al., 2023; Uxó, 2024). Dao et al. (2023) find that fiscal measures aimed at lowering inflation following the energy price shock of 2022 successfully contributed to stabilising inflation and output in the euro area, lowering the inflation overshoot by 2 percentage points and potentially preventing a subsequent undershoot.

In addition to measures aimed at lowering inflation, many fiscal authorities opted for targeted cash transfers to vulnerable households. Amaglobeli et al. (2023) argue that such measures are less costly and avoid tampering with market signals and are, therefore, preferable to broader-based measures that prevent domestic prices from rising in line with spikes in international prices. In contrast, the latter directly affect headline inflation and indirectly affect core inflation, thereby exerting downward pressure on inflation expectations. Furthermore, broad-based measures can be designed in a manner propitious to preserving the positive effects of high market prices. For example, the German 'gas price brake' was implemented as a two-tier pricing system, lowering the price of gas for a base quota while allowing market rates to prevail at the margin, thereby providing much-needed support to households while maintaining an incentive to save gas (Weber et al., 2023).

Given the targeted nature of fiscal policy, it is common for central bankers, such as Bandera et al. (2023), to consider fiscal policy as the first line of defence in response to negative supply shocks. However, fiscal policy's trade-offs and constraints will also intensify the more persistent and recurring such shocks become. This is why monetary and fiscal policy should work in a more coordinated manner, as espoused by the adaptive-IT regime, to ensure all policy tools available are supporting the long-term supply-side resilience of the economy. Strategies to ease fiscal policy's constraints, so that it is better able to prevent and mitigate such shocks while also investing in mitigation and adaptation, will also become increasingly necessary.

This report acknowledges, but does not discuss, important fiscal policy issues related to climate change. These include 'climate debt', climate-related fiscal deficits, the quantification of the need for increased public investment in the transition, subsidies, taxes and the use of parafiscal policies and institutions, such as development banks, during the transition. However, we emphasise that coordination between fiscal and monetary policies is becoming increasingly urgent, especially in light of current fiscal pressures. Rising debt-servicing costs are intensifying financial and political pressure to significantly tighten fiscal policy to avoid looming debt crises. Policymakers must identify ways of carefully and prudently managing such constraints. Financing the transition to net zero may, in some countries and regions, require innovative approaches, such as leveraging the consolidated public-sector balance sheet to pool risk on a broader basis (Draghi, 2024) and finding new tax bases at the national and/or international levels.

Implementing adaptive inflation targeting

The adaptive-IT framework can be viewed as an evolution of FIT for a 'hotter world' in which there are more frequent, persistent supply shocks – conditions under which central banks may alter their inflation targets and/or accept bigger fluctuation bands. It is preferable to prepare and clarify how inflation targeting will operate in a hotter world before supply-side instability intensifies, particularly in light of recent credibility challenges for inflation-targeting regimes, such as undershooting in the post-Global Financial Crisis and COVID-19 periods and overshooting during the more recent 2021-22 inflation surge. We consider the conditions and evidence base necessary to effect a credible shift to adaptive-IT, as summarised in Table 5.2.

First, central banks must assess the suitability of their inflation forecasting frameworks for an era of greater climate-related supply-side uncertainty. For instance, the recent Bernanke review of the Bank of England's forecasting framework recommended "greater attention to, and ongoing review of, supply-side elements and their role in the determination of inflation and growth" (Bernanke, 2024: 8). Refraining from such improvements would increase the likelihood of inflation forecasts producing major forecasting errors of the kind seen in recent years, whereas better models and an expansion of the suite of models could point towards the risk of more persistent inflationary pressures, which should prompt policymakers to engage with proposals on how to address them. However, the significant uncertainty involved in the dynamics explored in this report suggests that forecasting frameworks, even if improved, may not capture the scale of the risks on the horizon. The mere plausibility, and potential severity, of a scenario of more frequent, severe and persistent supply shocks should be sufficient justification for central bankers to explore how to navigate such conditions.

Second, if central banks choose to adopt adaptive-IT, they must consider the appropriate timing of such a shift in their framework. Although central banks frequently introduce new facilities in times of crisis (Dikau et al., 2021), changes to the monetary framework in times of instability could be taken as an admission of defeat (Pisani-Ferry and Mahfouz, 2023). Therefore, the implementation of adaptive-IT frameworks should occur in times of relative stability, when inflation is at or near target. This is especially the case in EMDEs, where changes to central bank targets and frameworks are particularly delicate and must be conditional on building sufficient credibility by achieving the previous target.[10] If central banks wait until a scenario of more persistent, frequent and severe supply shocks materialises, it will become increasingly challenging to introduce changes to the monetary framework without damaging their credibility. This highlights the urgency of considering adaptive-IT before supply-side volatility intensifies further.

Lastly, to further minimise any risks to credibility and maximise the efficiency of the proposed regime, central banks should collectively coordinate their communication and implementation of such a shift. As climate change is a global phenomenon, internationally coordinated communication on the merits of such a shift in inflation-targeting frameworks could take place in the context of regular meetings at the BIS or during the annual gatherings of the World

[10] Though it may seem counterintuitive, there is an important reason why central banks operating in an above-target inflationary environment may wish to incur the costs of disinflation (which may be particularly high if anticipation of a change in the target increases inflation expectations) before adapting the framework to allow some reinflation. Raising the target while inflation is above the original target would reveal a greater propensity to avoid the cost of disinflation, suggesting that the same approach might be taken in the face of future deviations. Conversely, reaching the target before adjusting it would demonstrate a commitment to convergence. In practice, however, this sequencing may be challenging, particularly if supply-side instability has already intensified.

Bank, International Monetary Fund and/or G20. Communication should emphasise that this represents an evolution in inflation targeting, retaining the good of the existing frameworks while including new features to ensure preparedness for the challenges ahead. This coordinated approach would reinforce the perception that climate-related supply-side risks were a global problem to be addressed collectively, rather than an ad hoc issue of a particular central bank.

Table 5.2. Implementing a shift from flexible to adaptive inflation targeting

Feature	Flexible inflation targeting	Adaptive inflation targeting	Conditions for shift to adaptive-IT
Inflation forecasting	Uses existing models and economic data to project inflation	Assesses additional inflationary risks from climate-related supply disruptions	Improved forecasting frameworks help to identify new supply-side risks
Forecast horizon	Typically spans one to two years	Extends over a longer horizon of three or more years	Forecasts show persistent inflationary pressures at the three-year-plus horizon
Policy rate decision	Tightens policy in response to persistent cost-push inflation	'Looks through' supply shocks to a greater degree	Evidence of the macroeconomic benefits of 'looking through'
Analysis of outcome	Deems the policy reaction to be adequate if the target is reached within the horizon	Assesses wider economic outcomes of convergence within the new horizon	Evidence regarding trade-offs and discussion of how to balance them
Communication	Justifies policy rate and path under the existing target and horizon	Justifies policy rate and path under the new target/bands and horizon	Internationally coordinated communication on merits of the new framework

Source: Authors

6. Conclusion

Central banks have made significant progress on incorporating climate risks into their monetary policy frameworks to address the economic and financial challenges posed by climate change. Key developments include conducting climate scenario analyses to evaluate the financial system's resilience to climate-related risks, exploring how climate change affects price stability and monetary policy transmission, integrating climate variables into forecasting frameworks, fostering collaboration through initiatives like the Network for Greening the Financial System (NGFS) and, in some cases, integrating sustainability considerations into monetary operations such as collateral frameworks and quantitative easing programmes. Despite this progress, a critical area remains underexplored: the challenges that inflation-targeting central banks may face if confronted with more frequent, persistent and severe climate-related supply shocks.

Unlike demand shocks, supply shocks create trade-offs for central banks and, unlike transitory supply shocks, persistent supply shocks can lead to a systematic and prolonged overshooting of inflation targets and undermine long-term macroeconomic stability. A small number of senior figures in the central banking community have recently begun to highlight the risks of a future of intensified supply-side volatility (Brainard, 2022; Schnabel, 2023; Maechler, 2024; Bénassy-Quéré, 2024). Building on these analyses, this report aims to spark a policy discussion on adaptive inflation targeting, with a view to equipping central banks with a framework, analysis and toolkit that enables them to better navigate these supply-side disruptions. To maintain credibility and ensure the smooth implementation of possible changes to existing inflation-targeting regimes, central banks must communicate these changes clearly in times of relative stability when inflation is at or around target.

References

Ademmer M, Jannsen N, Mösle S (2020) *Extreme weather events and economic activity: The case of low water levels on the Rhine river*. Kiel: Kiel Institute for the World Economy. www.ifw-kiel.de

Adolfsen JF, Lappe M-S (2023) Risks from global food commodity prices from El Niño. ECB Economic Bulletin, Issue 6/2023. Frankfurt am Main: European Central Bank. https://www.ecb.europa.eu/pub/economic-bulletin/focus/2023/html/ecb.ebbox202306_01~36e78cc75e.en.html

Adrian T (2021) *Review of Monetary Policy Frameworks*. Speech at the Central Banking Magazine's Reserve Management Americas Workshop, 16 March.

Agénor PR, Pereira da Silva LA (2019) *Integrated inflation targeting - Another perspective from the developing world*. Basel: Bank for International Settlements. https://www.bis.org/publ/othp30.htm

Aghion P, Bergeaud A, De Ridder M, Van Reenen J (2024) *Lost in Transition: Financial Barriers to Green Growth*. INSEAD Working Paper. SSRN, 25 March. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4771433

Aiyer S, Chen J, Ebeke C, et al. (2023) *Geo-Economic Fragmentation and the Future of Multilateralism*. Washington, DC: International Monetary Fund. https://www.imf.org/en/Publications/Staff-Discussion-Notes/Issues/2023/01/11/Geo-Economic-Fragmentation-and-the-Future-of-Multilateralism-527266

Akinci O, Benigno G, Clark H, et al. (2023) Global Supply Chain Pressure Index: The China Factor. Blog post, 6 January. New York, Liberty Street Economics, Federal Reserve Bank of New York. https://libertystreeteconomics.newyorkfed.org/2023/01/global-supply-chain-pressure-index-the-china-factor/

Aladangady A, Aron-Dine S, Dunn W, et al. (2017) *The Effect of Hurricane Matthew on Consumer Spending*. SSRN, 20 October. https://ssrn.com/abstract=3056155

Allen T, Boullot M, Dées S, et al. (2023) *Using Short-Term Scenarios to Assess the Macroeconomic Impacts of Climate Transition*. Banque de France Working Paper Series No. 922. https://www.banque-france.fr/en/publications-and-statistics/publications/using-short-term-scenarios-assess-macroeconomic-impacts-climate-transition

Almeida E, Lagoa D, Vasudhevan T (2024) *Hidden harms: the economic and financial consequences of deforestation and its underlying drivers*. London, Centre for Economic Transition Expertise. https://www.lse.ac.uk/cetex/publications/hidden-harms-the-economic-and-financial-consequences-of-deforestation-and-its-underlying-drivers/

Altavilla C, Boucinha M, Pagano M, et al. (2024) *Climate risk, bank lending and monetary policy*. European Central Bank Working Paper Series No. 2969. https://www.ecb.europa.eu/press/research-publications/working-papers/html/index.en.htmlc

Amaglobeli D, Gu M, Hanedar E, et al. (2023) *Policy Responses to High Energy and Food Prices*. IMF Working Paper Working Paper No. 2023/074. https://www.imf.org/en/Publications/WP/Issues/2023/03/24/Policy-Responses-to-High-Energy-and-Food-Prices-531343

Angeli M, Archer C, Batten S, et al. (2022) Climate change: possible macroeconomic implications. Quarterly Bulletin 2022 Q4. London: Bank of England. https://beta.bankofengland.co.uk/quarterly-bulletin/2022/2022-q4/climate-change-possible-macroeconomic-implications

Auer R, Borio C, Filardo A (2017) *The globalisation of inflation: the growing importance of global value chains*. BIS Working Papers No. 602, January. https://www.bis.org/publ/work602.pdf

Bandera N, Barnes L, Chavaz M, Tenreyro S, Von Dem Berge L (2023) *Monetary Policy in the Face of Supply Shocks: The Role of Inflation Expectations*. ECB Forum on Central Banking, 26-28 June. https://www.ecb.europa.eu/press/conferences/ecbforum/shared/pdf/2023/Tenreyro_paper.pdf

Bao X, Sun P, Li J (2023) The impacts of tropical storms on food prices: Evidence from China. *American Journal of Agricultural Economics* 105(2): 576–596. https://onlinelibrary.wiley.com/doi/abs/10.1111/ajae.12330
Barattieri A, Borda P, Brugnoli A, et al. (2023) The short-run, dynamic employment effects of natural disasters: New insights from Puerto Rico. *Ecological Economics* 205: 107693. https://www.sciencedirect.com/science/article/pii/S0921800922003548
Barmes D, Schröder Bosch J (2024) *Inflation as an Ecological Phenomenon*. London: Positive Money. https://positivemoney.org/publications/inflation-as-an-ecological-phenomenon/
Beirne J, Dafermos Y, Kriwoluzky A, et al. (2024) Weather-related disasters and inflation in the euro area. *Journal of Banking and Finance* 169: 107298. https://www.sciencedirect.com/science/article/pii/S0378426624002127?via=ihub
Beirne J, Renzhi N, Volz U (2021) Feeling the heat: Climate risks and the cost of sovereign borrowing*. International Review of Economics and Finance* 76: 920–936. https://doi.org/10.1016/j.iref.2021.06.019
Belasen AR, Polachek SW (2008) How Hurricanes Affect Wages and Employment in Local Labor Markets. *American Economic Review* 98(2): 49–53. https://www.aeaweb.org/articles?id=10.1257/aer.98.2.49
Bénassy-Quéré A (2024) The policy mix in a world of supply shocks. Speech at the University of Bordeaux, 3 October. https://www.banque-france.fr/en/governors-interventions/policy-mix-world-supply-shocks
Benigno G, Hofmann B, Nuño Barrau G, et al. (2024) Quo vadis, r*? The natural rate of interest after the pandemic. BIS Quarterly Review, 4 March. https://www.bis.org/publ/qtrpdf/r_qt2403b.htm
Bernanke B, Laubach T, Mishkin F, Posen A (1999) *Inflation targeting: lessons from international experience*. Princeton, NJ: Princeton University Press. https://www.jstor.org/stable/j.ctv301gdr
Bernanke B (2024) *Forecasting for monetary policy making and communication at the Bank of England: a review*. London: Bank of England. https://www.bankofengland.co.uk/independent-evaluation-office/forecasting-for-monetary-policy-making-and-communication-at-the-bank-of-england-a-review/forecasting-for-monetary-policy-making-and-communication-at-the-bank-of-england-a-review
Bin O, Landry CE (2013) Changes in implicit flood risk premiums: Empirical evidence from the housing market. *Journal of Environmental Economics and management* 65(3): 361–376. https://www.sciencedirect.com/science/article/pii/S0095069612001179
Blanchard O (2022) It is time to revisit the 2% inflation target. *Financial Times*, 28 November. https://www.ft.com/content/02c8a9ac-b71d-4cef-a6ff-cac120d25588
Bloesch J (2022) *A New Framework for Targeting Inflation: Aiming for a Range of 2 to 3.5 Percent*. New York: Roosevelt Institute. https://rooseveltinstitute.org/publications/a-new-framework-for-targeting-inflation-aiming-for-a-range-of-2-to-3-5-percent/
Boissay F, Collard F, Manea C, Shapiro A (2023) *Monetary Tightening, Inflation Drivers and Financial Stress*. BIS Working Paper No. 1155. Basel: Bank for International Settlements. https://www.bis.org/publ/work1155.htm
Bonciani D, Masolo RM, Sarpietro S (2024) *How food prices shape inflation expectations and the monetary policy response*. Bank of England Staff Working Paper No. 1,094. www.bankofengland.co.uk/working-paper/staff-working-papers
Boneva L, Ferrucci G (2022) *Inflation and climate change: the role of climate variables in inflation forecasting and macro modelling*. London: SOAS Centre of Sustainable Finance, LSE Grantham Research Institute on Climate Change and the Environment. https://inspiregreenfinance.org/publications/inflation-and-climate-change-the-role-of-climate-variables-in-inflation-forecasting-and-macro-modelling/.
Borio C, Lombardi M, Yetman J, Zakrajšek E (2023) *The two-regime view of inflation*. BIS Papers No. 133. Basel: Bank for International Settlements. https://www.bis.org/publ/bppdf/bispap133.htm
Borio C (2022) *Inflation: looking under the hood*. Speech at the BIS Annual General Meeting, Basel, 26 June. https://www.bis.org/speeches/sp220626a.pdf
Brainard L (2022) What can we learn from the pandemic and the war about supply shocks,

inflation, and monetary policy? Speech to the 21st BIS Annual Conference "Central Banking after the Pandemic: Challenges Ahead", Basel, Bank for International Settlements, 24 June. https://www.bis.org/review/r221128l.htm.
Bremus F, Dany-Knedlik G, Schlaak T (2020) Price stability and climate risks: sensible measures for the European Central Bank. DIW Weekly Report 14/2020: 205–213. Berlin: DIW Berlin. https://doi.org/10.18723/diw_dwr:2020-14-1.
Brunnermeier MK, Garicano L, Lane PR, Pagano M, Reis R, Santos T, Thesmar D, Van Nieuwerburgh S, Vayanos D (2016) *The sovereign-bank diabolic loop and ESBies*. *American Economic Review* 106(5): 508–512. https://www.aeaweb.org/articles?id=10.1257/aer.p20161107
Burke M, Hsiang SM, Miguel E (2015) Global non-linear effect of temperature on economic production. *Nature* 527(7577): 235–239. https://www.nature.com/articles/nature15725
Carrière-Swallow Y, Deb P, Furceri D, et al. (2023) Shipping costs and inflation. *Journal of International Money and Finance* 130: 102771. https://www.sciencedirect.com/science/article/pii/S0261560622001747
Cashin P, Mohaddes K and Raissi M (2017) Fair weather or foul? The macroeconomic effects of El Niño. *Journal of International Economics* 106: 37–54. https://www.sciencedirect.com/science/article/pii/S0022199617300120
Cesa-Bianchi A, Ferrero A (2021) *The transmission of Keynesian supply shocks*. Bank of England Staff Working Paper 934. https://www.bankofengland.co.uk/working-paper/2021/the-transmission-of-keynesian-supply-shocks
Cevik S, Gwon G (2024) This is going to hurt: Weather anomalies, supply chain pressures and inflation. *International Economics* 180: 100560. https://www.sciencedirect.com/science/article/pii/S2110701724000830
Cevik S, Jalles JT (2023) *Eye of the Storm: The Impact of Climate Shocks on Inflation and Growth*. Working Paper No. 2023/087. Washington, DC: International Monetary Fund. https://www.imf.org/en/Publications/WP/Issues/2023/04/28/Eye-of-the-Storm-The-Impact-of-Climate-Shocks-on-Inflation-and-Growth-532661
Chavleishvili S, Moench E (2024) Natural Disasters as Macroeconomic Tail Risks. SSRN, 27 November. Forthcoming in the *Journal of Econometrics*. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4657195
Ciccarelli M, Marotta F (2024) Demand or Supply? An empirical exploration of the effects of climate change on the macroeconomy. *Energy Economics* 129: 107163. https://www.sciencedirect.com/science/article/pii/S0140988323006618
Ciccarelli M, Kuik F, Martínez Hernández C (2023) *The asymmetric effects of weather shocks on euro area inflation*. Working Paper No. 2798. Frankfurt am Main: European Central Bank. https://doi.org/10.2866/604002
Ciccarelli M, Mojon BB (2010) Global Inflation. *The Review of Economics and Statistics* 92(3): 524–535. http://direct.mit.edu/rest/article-pdf/92/3/524/1614871/rest_a_00008.pdf
Clarida R (2020) The Federal Reserve's New Monetary Policy Framework: A Robust Evolution. Speech at the "The Economy and Monetary Policy" event hosted by the Hutchins Center on Fiscal and Monetary Policy at the Brookings Institution, Washington, DC, 16 November. https://www.bis.org/review/r201117d.htm
Crofils C, Gallic E, Vermandel G, et al. (2024) *The Dynamic Effects of Weather Shocks on Agricultural Production*. AMSE Working Papers. HAL SHS, 22 July. https://shs.hal.science/halshs-04443037v1
Dao M C, Dizioli A, Jackson C, Gourinchas P-O, Leigh D (2023) *Unconventional Fiscal Policy in Times of High Inflation*. Working Paper No. 2023/178. Washington, DC: International Monetary Fund. https://www.imf.org/en/Publications/WP/Issues/2023/08/31/Unconventional-Fiscal-Policy-in-Times-of-High-Inflation-537454
De Winne J, Peersman G (2021) The adverse consequences of global harvest and weather disruptions on economic activity. *Nature Climate Change* 11(8): 665–672. https://www.nature.com/articles/s41558-021-01102-w
Dhingra S (2023) Price and monetary policy transmission in a globalised economy. Speech at Manchester Metropolitan University, 13 June. https://www.bankofengland.co.uk/speech/2023/june/swati-dhingra-speech-manchester-met-uni.

Diaz EM, Cunado J, Perez de Gracia F (2024) Global drivers of inflation: The role of supply chain disruptions and commodity price shocks. *Economic Modelling* 140: 106860. https://www.sciencedirect.com/science/article/pii/S0264999324002177
Dikau S, Volz U (2021) Central bank mandates, sustainability objectives and the promotion of green finance. *Ecological Economics* 184: 107022. https://www.sciencedirect.com/science/article/pii/S092180092100080X
Dikau S, Robins N, Volz U (2021) *A Toolbox of Sustainable Crisis Response Measures for Central Banks and Supervisors – Second Edition: Lessons from Practice*. London: Grantham Research Institute on Climate Change and the Environment. https://www.lse.ac.uk/granthaminstitute/publication/a-toolbox-of-sustainable-crisis-response-measures-for-central-banks-and-supervisors-second-edition/
Draghi M (2024) *The future of European competitiveness*. Brussels: European Commission. https://commission.europa.eu/topics/strengthening-european-competitiveness/eu-competitiveness-looking-ahead_en#paragraph_47059.
Drudi F, Moench E, Holthausen C, et al. (2021) *Climate change and monetary policy in the euro area*. ECB Occasional Paper No. 2021/271. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3928292.
Faccia D, Parker M, Stracca L (2021) *Feeling the heat: extreme temperatures and price stability*. European Central Bank Working Paper No. 2626. https://doi.org/10.2866/185550
Federal Reserve Bank of New York (n.d.) Global Supply Chain Pressure Index (GSCPI). New York. https://www.newyorkfed.org/research/policy/gscpi#/overview.
Ferriani F, Gazzani A, Natoli F (2023) *Flight to climatic safety: local natural disasters and global portfolio flows*. Bank of Italy Working Paper No. 1420. https://www.bancaditalia.it/pubblicazioni/temi-discussione/2023/2023-1420/
Fornaro L, Wolf M (2023) The scars of supply shocks: Implications for monetary policy. *Journal of Monetary Economics* 140: S18–S36. https://www.sciencedirect.com/science/article/pii/S0304393223000417
Fratzscher M, Grosse-Steffen C, Rieth M (2020) Inflation targeting as a shock absorber. *Journal of International Economics* 123: 103308. https://www.sciencedirect.com/science/article/pii/S0022199620300271
Furceri D, Loungani P, Zdzienicka A (2018) The effects of monetary policy shocks on inequality. *Journal of International Money and Finance* 85: 168–186. https://doi.org/10.1016/j.jimonfin.2017.11.004
Furceri D, Loungani P, Simon J, et al. (2016) Global food prices and domestic inflation: Some cross-country evidence. *Oxford Economic Papers* 68(3): 665–687. https://academic.oup.com/oep/article-abstract/68/3/665/1753000
Guérin P (2023) What are the effects of monetary policy on productivity? *Economics Letters* 233: 111440. https://www.sciencedirect.com/science/article/pii/S0165176523004664
Guerrieri V, Lorenzoni G, Straub L, et al. (2020) Macroeconomic implications of COVID-19: can negative supply shocks cause demand shortages? NBER Working Paper Series 26918. http://www.nber.org/papers/w26918.
Groen JA, Polivka AE (2008) The effect of Hurricane Katrina on the labor market outcomes of evacuees. *American Economic Review* 98(2): 43-48. https://www.aeaweb.org/articles?id=10.1257/aer.98.2.43
Hammond G (2012) *State of the art inflation targeting*. London: Centre for Central Banking Studies, Bank of England. https://www.bankofengland.co.uk/ccbs/state-of-the-art-of-inflation-targeting.
Heemskerk I, Nerlich C and Parker M (2022) Turning down the heat: how the green transition supports price stability. Blog post, 9 November. Frankfurt am Main: European Central Bank. https://www.ecb.europa.eu/press/blog/date/2022/html/ecb.blog221109~6ad307c8cf.en.html.
Heinen A, Khadan J, Strobl E (2019) The price impact of extreme weather in developing countries. *Economic Journal* 129(619): 1327–1342. https://academic.oup.com/ej/article-abstract/129/619/1327/5320374
Holston K, Laubach T, Williams JC (2017) Measuring the natural rate of interest: International trends and determinants. *Journal of International Economics* 108: S59–S75. https://www.sciencedirect.com/science/article/pii/S0022199617300065

Iacoviello M, Caldara D, Penn M, et al. (2024) *Do Geopolitical Risks Raise or Lower Inflation?* SSRN, 3 June. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4852461.
Iliyasu J, Mamman SO, Ahmed UA (2023) Impact of climate change on output and inflation in Africa's largest economies. *Climate and Development* 15(10): 864–875. https://www.tandfonline.com/doi/full/10.1080/17565529.2023.2172315
IPCC (2021) Weather and Climate Extreme Events in a Changing Climate. In: *Sixth Assessment Report*: 1515-1765. https://www.ipcc.ch/report/ar6/wg1/chapter/chapter-11/
Jirophat C, Manopimoke P, Suwanik S (2022) *The Macroeconomic Effects of Climate Shocks in Thailand.* Bangkok: Puey Ungphakorn Institute for Economic Research. https://www.pier.or.th/files/dp/pier_dp_188.pdf
Jordà Ò, Singh SR, Taylor AM (2024) *The Long-Run Effects of Monetary Policy*. Federal Reserve Bank of San Francisco Working Paper 2020-01. https://www.frbsf.org/research-and-insights/publications/working-papers/2023/05/the-long-run-effects-of-monetary-policy/.
Kabundi A, Mlachila M, Yao J (2022) *How Persistent Are Climate-Related Price Shocks? Implications for Monetary Policy*. International Monetary Fund Working Paper 2022/207. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4272242#
Kamber G, Mcdonald C, Price G (2013) *Drying out: Investigating the economic effects of drought in New Zealand*. Wellington: Reserve Bank of New Zealand. https://www.rbnz.govt.nz/hub/publications/analytical-note/2013/an2013-02
Kedward K, Gabor D, Ryan-Collins J (2024) Carrots with(out) sticks: Credit Policy and the Limits of Green Central Banking. *Review of International Political Economy* 31(5): 1593–1617. https://doi.org/10.1080/09692290.2024.2351838
Kedward K, Ryan-Collins J, Chenet H (2022) Biodiversity loss and climate change interactions: financial stability implications for central banks and financial supervisors. *Climate Policy* 23(6): 763-781. https://www.tandfonline.com/doi/full/10.1080/14693062.2022.2107475
Kim HS, Matthes C, Phan T (2022) Severe Weather and the Macroeconomy. Federal Reserve Bank of Richmond Working Paper No. 21-14R. https://www.richmondfed.org/publications/research/working_papers/2021/wp_21-14
Klomp J (2020) Do natural disasters affect monetary policy? A quasi-experiment of earthquakes. *Journal of Macroeconomics* 64: 103164. https://www.sciencedirect.com/science/article/pii/S0164070418304026
Korenok O, Munro D, Chen J (2023) Inflation and Attention Thresholds. *The Review of Economics and Statistics*. https://doi.org/10.1162/rest_a_01402
Kotz M, Kuik F, Lis E, Nickel C (2023) *The Impact of Global Warming on Inflation: Averages, Seasonality and Extremes*. European Central Bank Working Paper No. 2821. https://doi.org/10.2866/46035
Kotz M, Kuik F, Lis E, Nickel C (2024) Global warming and heat extremes to enhance inflationary pressures. *Communications Earth & Environment* 5(116). https://www.nature.com/articles/s43247-023-01173-x
Kuik F, Modery W, Nickel C, Parker M (2023) *The price of inaction: what a hotter climate means for monetary policy*. The ECB Blog. https://www.ecb.europa.eu/press/blog/date/2023/html/ecb.blog231218~6291e67d1e.en.html
Laurentjoye T (2024) Inflation, Monetary Policy and the Hierarchy of Consumer Goods. In: J. Jespersen, F. Olesen, M. Byrialsen (eds.) *Post-Keynesian Economics for the Future: Sustainability, Policy and Methodology*. Edward Elgar Publishing: 152-168.
Lawrence M, Janzwood S, Homer-Dixon T (2022). *What Is a Global Polycrisis? And How Is It Different from a Systemic Risk?* Victoria, BC: Cascade Institute. https://cascadeinstitute.org/technical-paper/what-is-a-global-
Leslie J (2022) How Climate Change Is Disrupting the Global Supply Chain. *YaleEnvironment360*, 10 March. https://e360.yale.edu/features/how-climate-change-is-disrupting-the-global-supply-chain
Levieuge G (2009) The bank capital channel and counter-cyclical prudential regulation in a DSGE model. *Louvain Economic Review* 75(4): 425-460. https://www.researchgate.net/publication/46565955_The_Bank_Capital_Channel_and_Counter-Cyclical_Prudential_Regulation_in_a_DSGE_model

Lez P (2024) The ECB's operational framework review: why? how? *Banque de France Eco Notepad* No. 366, 18 September. https://www.banque-france.fr/en/publications-and-statistics/publications/ecbs-operational-framework-review-why-how
Löscher A, Kaltenbrunner A (2023) Climate Change and Macroeconomic Policy Space in Developing and Emerging Economies. *Journal of Post Keynesian Economics* 46(1): 113–141. https://doi.org/10.1080/01603477.2022.2084630
Lucidi FS, Pisa MM, Tancioni M (2024) The Effects of Temperature Shocks on Energy Prices and Inflation in the Euro Area. *European Economic Review*, 166: 104771. https://doi.org/10.1016/j.euroecorev.2024.104771
Ma Y, Zimmermann K (2023) *Monetary Policy and Innovation*. SSRN, 6 October. https://ssrn.com/abstract=4576686.
Madeira C, Madeira J, Santos Monteiro P (2023) *The Origins of Monetary Policy Disagreement: The Role of Supply and Demand Shocks*. BIS Working Paper No. 1118. Basel: Bank for International Settlements. https://www.bis.org/publ/work1118.htm
Maechler AM (2024) Monetary policy in an era of supply headwinds: do the old principles still stand? Speech at the London School of Economics, London, 2 October. https://www.bis.org/speeches/sp241002.pdf.
Marchiori L, Maystadt JF, Schumacher I (2012) The impact of weather anomalies on migration in sub-Saharan Africa. *Journal of Environmental Economics and Management* 63(3): 355–374. https://www.sciencedirect.com/science/article/pii/S0095069612000150
Marsden L, Ryan-Collins J, Abrams JF, Lenton TM (2024) Ecosystem Tipping Points: Understanding Risks to the Economy and Financial System. London: UCL Institute for Innovation and Public Purpose. https://www.ucl.ac.uk/bartlett/public-purpose/sites/bartlett_public_purpose/files/ecosystem_tipping_points_policy_report_iipp.pdf
Martin P, Whiteside J, McKay F, Santhakumar S (2024) *Conflicts of Interest: The Cost of Investing in the Energy Transition in a High Interest-Rate Era*. Edinburgh: Wood Mackenzie. https://www.woodmac.com/horizons/energy-transition-investing-in-a-high-interest-rate-era/
McCoy SJ, Walsh RP (2018) Wildfire risk, salience & housing demand. *Journal of Environmental Economics and Management* 91: 203-228. https://www.sciencedirect.com/science/article/pii/S0095069617305181
McCracken M, Khánh Ngân T (2023) What Do Components of Key Inflation Measures Say about Future Inflation? Blog post, 25 May. Federal Reserve Bank of St. Louis. https://www.stlouisfed.org/on-the-economy/2023/may/components-key-inflation-measures-say-future-inflation
McKibbin WJ, Hogan M, Noland M (2024) *The International Economic Implications of a Second Trump Presidency*. Peterson Institute for International Economics Working Paper No. 24-20. SSRN, 13 November. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4968651
McKibbin WJ, Morris AC, Wilcoxen PJ, et al. (2020) Climate change and monetary policy: Issues for policy design and modelling. *Oxford Review of Economic Policy* 36(3): 579–603. https://academic.oup.com/oxrep/article-abstract/36/3/579/6104323
Melodia L, Karlsson K (2022) *Energy Price Stability: The perils of fossil fuels and the promise of renewables*. New York: Roosevelt Institute. https://rooseveltinstitute.org/publications/energy-price-stability/.
Moessner R (2022) *Effects of Precipitation on Food Consumer Price Inflation*. CESifo Working Paper No. 9961. Munich: CESifo Network. https://www.cesifo.org/en/publications/2022/working-paper/effects-precipitation-food-consumer-price-inflation
Mongelli FP, Pointner W, Van den End JW (2024) The effects of climate change on the natural rate of interest: A critical survey. *WIREs Climate Change* 15(2): e873. https://wires.onlinelibrary.wiley.com/doi/full/10.1002/wcc.873
Morin E, Kern AB (1999) *Homeland Earth: A Manifesto for the New Millenium. Advances in Systems Theory, Complexity, and the Human Sciences*. Cresskill, NJ: Hampton Press.
Mukherjee K, Ouattara B (2021) Climate and Monetary Policy: Do Temperature Shocks Lead to Inflationary Pressures? *Climatic Change* 167(32). https://doi.org/10.1007/s10584-021-03149-2
Nam K (2021) Investigating the effect of climate uncertainty on global commodity markets.

Energy Economics 96: 105123. https://www.sciencedirect.com/science/article/pii/S0140988321000281
NGFS (2021) *Adapting central bank operations to a hotter world*: *Reviewing some options*. Paris: Network for Greening the Financial System. https://www.ngfs.net/en/adapting-central-bank-operations-hotter-world-reviewing-some-options
NGFS (2024a) *Acute Physical Impacts from Climate Change and Monetary Policy*. Paris: Network for Greening the Financial System. https://www.ngfs.net/en/acute-physical-impacts-climate-change-and-monetary-policy
NGFS (2024b) *Climate macroeconomic modelling handbook*. Paris: Network for Greening the Financial System. https://www.ngfs.net/en/climate-macroeconomic-modelling-handbook.
Nobletz C, Svartzman R, Dikau S (2024) *The EU's Dependency on Critical Materials*: *Meeting Decarbonisation Targets in the Context of Geopolitical Risks*. Milan: IEP Bocconi and CETEx. https://iep.unibocconi.eu/policy-brief-eus-dependency-critical-materials
Ocampo JA, Ojeda-Joya J (2022) Supply shocks and monetary policy responses in emerging economies. *Latin American Journal of Central Banking* 3(4): 100071. https://www.sciencedirect.com/science/article/pii/S2666143822000254
Ortega F, Taspınar S (2018) Rising sea levels and sinking property values: Hurricane Sandy and New York's housing market. *Journal of Urban Economics* 106: 81-100. https://www.sciencedirect.com/science/article/pii/S0094119018300354
Ouattara B, Soutar C, Waight G (2024) Climate threat and price stability: A case study of Belize. *Review of Development Economics*: Online Version of Record before inclusion in an issue. https://onlinelibrary.wiley.com/doi/full/10.1111/rode.13135
Parker M (2018a). The Impact of Disasters on Inflation. *Economics of Disasters and Climate Change* 2(1): 21–48. https://doi.org/10.1007/s41885-017-0017-y
Parker M (2018b) How global is "global inflation"? *Journal of Macroeconomics* 58: 174–197. https://www.sciencedirect.com/science/article/pii/S0164070418301368
Peersman G (2022) International Food Commodity Prices and Missing (Dis)Inflation in the Euro Area. *Review of Economics and Statistics* 104(1): 85–100. https://direct.mit.edu/rest/article-abstract/104/1/85/97682/International-Food-Commodity-Prices-and-Missing
Pereira da Silva L, Kharroubi E, Kohlscheen E, Lombardi M, Mojon B (2022) *Inequality Hysteresis and the Effectiveness of Macroeconomic Stabilisation Policies*. Basel: Bank for International Settlements. https://www.bis.org/publ/othp50.htm
Pisani-Ferry J, Mahfouz S (2023) *The economic implications of climate action*. Paris: France Strategies. https://www.strategie.gouv.fr/english-articles/economic-implications-climate-action
Ritchie H, Rosado P (2024) Is the number of natural disasters increasing? *Our World in Data*, 3 June. https://ourworldindata.org/disaster-database-limitations.
Schmidt TS, Steffen B, Egli F, Pahle M, Tietjen O, Edenhofer O (2019) Adverse Effects of Rising Interest Rates on Sustainable Energy Transitions. *Nature Sustainability* 2(9): 879–885. https://doi.org/10.1038/s41893-019-0375-2
Schnabel I (2022) The new age of energy inflation: climateflation, fossilflation and greenflation. Speech at a panel on "Monetary Policy and Climate Change" at The ECB and its Watchers XXII Conference, Frankfurt am Main, 17 March. https://www.ecb.europa.eu/press/key/date/2022/html/ecb.sp220317_2~dbb3582f0a.en.html.
Schnabel I (2023) The risks of stubborn inflation. European Central Bank. at the Euro50 Group conference on "New challenges for the Economic and Monetary Union in the post-crisis environment", Luxembourg, 19 June. https://www.ecb.europa.eu/press/key/date/2023/html/ecb.sp230619_1~2c0bdf2422.en.html.
Shapiro AH (2024) Decomposing Supply- and Demand-Driven Inflation. *Journal of Money, Credit, and Banking*. Online Version of Record before inclusion in an issue. https://onlinelibrary.wiley.com/doi/abs/10.1111/jmcb.13209
Somanathan E, Somanathan R, Sudarshan A, Tewari M (2021) The impact of temperature on productivity and labor supply: Evidence from Indian manufacturing. *Journal of Political Economy* 129(6): 1797-1827. https://www.journals.uchicago.edu/doi/10.1086/713733

Storm S (2021) Why the Rich Get Richer and Interest Rates Go Down. *Institute for New Economic Thinking*, 13 September. https://www.ineteconomics.org/perspectives/blog/why-the-rich-get-richer-and-interest-rates-go-down.
Swiss Re (2024) Beyond broken infrastructure – Swiss Re explores cascading effects of natural disasters and other key emerging risks. Press release, 12 June. Zurich. https://www.swissre.com/media/press-release/pr-20240612-beyond-broken-infrastructure.html.
Svensson LEO (1997) Inflation Forecast Targeting: Implementing and Monitoring Inflation Targets. *European Economic Review*, 41 (6): 1111-1146. https://www.sciencedirect.com/science/article/pii/S0014292196000554
Svensson LEO (2009) Flexible Inflation Targeting: Lessons from the Financial Crisis. Speech at the workshop "Towards a new framework for monetary policy? Lessons from the crisis", De Nederlandsche Bank, Amsterdam, 21 September 21. https://archive.riksbank.se/en/Web-archive/Published/Speeches/2009/Svensson-Flexible-Inflation-Targeting-Lessons-from-the-Financial-Crisis/index.html
Svensson LEO (2020) Monetary Policy Strategies for the Federal Reserve. *International Journal of Central Banking,* 16 (1): 133-193.
Thiede B, Gray C, Mueller V (2016) Climate variability and inter-provincial migration in South America, 1970–2011. *Global Environmental Change* 41: 228-240. https://www.sciencedirect.com/science/article/pii/S0959378016303909
Tooze A (2022) Welcome to the world of the polycrisis: Today disparate shocks interact so that the whole is worse than the sum of the parts. *Financial Times*, 28 October. https://www.ft.com/content/498398e7-11b1-494b-9cd3-6d669dc3de33.
UNCTAD (2024) *Climate and conflict collide on the high seas: UN warns of soaring costs and delay.* UN News. https://news.un.org/en/story/2024/02/1146862
Uxó J, Febrero E, Álvarez I (2024) Prices, markups and wages: inflation and its distributive consequences in Spain, 2021-2023. *Structural Change and Economic Dynamics*: In press, corrected proof. https://www.sciencedirect.com/science/article/pii/S0954349X24001504
Van't Klooster J, Weber IM (2024) *Closing the EU's Inflation Governance Gap: The limits of monetary policy and the case for a new policy framework for shockflation*. Brussels and Strasbourg: European Parliament Think Tank. https://www.europarl.europa.eu/thinktank/en/document/IPOL_STU(2024)755727
Ventosa-Santaulària D, Tapia E, Pérez-Peña AK (2024) Inflation dynamics under different weather regimes: Evidence from Mexico. *Ecological Economics* 220: 108179. https://www.sciencedirect.com/science/article/pii/S0921800924000764
Weber IM, Beckmann T, Thie JE (2023) The Tale of the German Gas Price Brake: Why We Need Economic Disaster Preparedness in Times of Overlapping Emergencies. *Intereconomics*, 58(1): 10–16. https://doi.org/10.2478/ie-2023-0004
Weber IM, Jauregui JL, Teixeira L, et al. (2022) *Inflation in Times of Overlapping Emergencies: Systemically Significant Prices from an Input-output Perspective*. Economics Department Working Paper Series 340. Amherst, MA: University of Massachusetts Amherst. https://peri.umass.edu/images/Weber-PERI-Inflation-Conf-WP.pdf
World Bank (2023) *International Debt Report 2023.* Washington, DC. https://www.worldbank.org/en/programs/debt-statistics/idr/products
Yusifzada T (2024) Evaluating the global impact of climate change on agricultural inflation: an innovative climate condition index approach. *Environment, Development and Sustainability* 26(7): 18411–18438. https://link.springer.com/article/10.1007/s10668-023-03394-8
Zhang P, Deschenes O, Meng K, Zhang J (2018) Temperature effects on productivity and factor reallocation: Evidence from a half million Chinese manufacturing plants. *Journal of Environmental Economics and Management* 88: 1-17. https://www.sciencedirect.com/science/article/pii/S0095069617304588