Finance, Nature and Food Transitions

The impact of potential financial climate and nature risk repricing on normative outcomes for food systems

September 2022

NATURE FINANCE

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Our use of Fibonacci sequence imagery is inspired by the association of this unique ratio with the maintenance of balance, and its appearance everywhere in nature- from the arrangement of leaves on a stem to atoms, uncurling ferns, hurricanes and celestial bodies.

Table of Contents

List of figures

List of tables

List of boxes

Glossary

AFOLU - Agriculture, Forestry and Other Land Use

BII - Biodiversity Intactness Index

ECB - European Central Bank

F&A – Food and Agriculture

GHG - Greenhouse Gases

IPCC – Intergovernmental Panel on Climate Change

IPR - Inevitable Policy Response

LULUCF - Land Use, Land-Use Change and Forestry

NBS – nature-based solutions

NGFS – Network for Greening the Financial System

NGO – Non-governmental organisation

SBTi – Science Based Targets

TCFD - Task Force on Climate-related Financial Disclosures

TNFD - Taskforce on Nature-related Financial Disclosures

Definitions - In this report, we often refer to:

- **the food system**, by which we mean a system that 'gathers all the elements (environment, people, inputs, processes, infrastructures, institutions) and activities that relate to the production, processing, distribution, preparation and consumption of food, and the outputs of these activities, including socio-economic and environmental outcomes'.[1] We often also refer to the food and agriculture sector (F&A), by which we mean the economic activities within the food system and which cover the AFOLU sector and related industry and services.
- **the financial system**, understood as a system that 'consists of institutional units and markets that interact, typically in a complex manner, for the purpose of mobilizing funds for investment, and providing facilities, including payment systems, for the financing of commercial activity'.[2]
- **an orderly transition,** similarly to the definition of the Network for Greening the Financial System, an orderly transition assumes climate policies are introduced early and become gradually more stringent.[3]
- **Biodiversity Intactness Index (BII)** - the average abundance of a large and diverse set of organisms in a given geographical area, relative to their reference populations.[4]

Executive summary

In the absence of appropriate policy to mitigate nature loss and Greenhouse Gas (GHG) emissions, an abrupt response by the financial sector to correct for accumulating nature and climate risks is increasingly possible. The food system's negative impact on nature and climate has created pressure for a transition towards higher sustainability. The financial system plays a key role by financing the food system, and is increasingly expected (by regulators, shareholders and clients) to factor in the nature and climate risks and impacts associated with its financing activities. At the same time, the capabilities of the financial sector to quantify climate and nature risks are advancing rapidly, alongside a greater awareness of the materializing climate and nature risks. If unaddressed, the combination of accumulated climate and nature risk, a looming 'inevitable' policy response,[5] and increasing financial sector awareness could lead to a sudden adjustment in risk pricing with broader consequences for the food system.

Comparing an abrupt 'financial risk-driven' transition to a transition facilitated by more orderly public policies illustrates the impacts associated with capital reallocation under uncertainty, and the role stakeholders can play in mitigating risks to the food system. In a transition driven by an abrupt financial sector response we see financiers suddenly reallocating capital away from the least sustainable activities in the food system. While this brings better outcomes for GHG emissions and nature loss, it also brings a sudden shock to the food system. Policymakers can facilitate a smoother transition through credible policies that better price GHG emissions and nature loss, and that support investments in, and economic adjustment toward sustainable activities, such as nature-based solutions (NBS) and improved agricultural production practices.

Our results indicate that a 'policy-facilitated' transition improves economic and social outcomes in the agricultural and food systems compared to a 'financial-risk driven transition, while also leading to better environmental outcomes. The 'policy-facilitated' transition improves social and economic outcomes in the agricultural and food system. In the 'financial risk-driven' transition, both employment and sectoral output fall over 2020-2050, with 15% (USD 575 billions) lower AFOLU output and 78 million fewer AFOLU jobs compared to the 'policy-facilitated' transition in 2050. These better outcomes in a 'policy-facilitated' scenario are achieved on the back of a more gradual shift in pricing, and better enabling conditions for sector transformation, including growing ecosystem restoration activities, greater innovation in new areas (like alternative proteins) and higher productivity. These same forces also mean that the increases in food prices associated with the transition are less steep in this scenario. Household expenditure on food falls faster in the 'policy-facilitated' scenario, leading to 3 million more people who can afford basic nutrition relative to the 'financial risk-driven' scenario. This suggests additional just transition issues that might require additional policy actions. At the same time, although both scenarios create similar long-term levels of environmental risk pricing, the 'policy-facilitated' scenario leads to better environmental outcomes bringing forward both net zero CO_2 emissions and nature recovery in AFOLU by about 10 years compared to the 'financial risk-driven' scenario.

In examining the case of Brazil specifically, we find similar but somewhat starker results, with a 'financial-risk driven' transition leading to relatively worse economic, social and environmental outcomes. Brazil's competitive advantage in both livestock and NBS production turn the transition into a positive for economic activity and jobs under both scenarios, although growth rates are much higher when policy facilitates the transition. However, the competitive advantage also results in higher land competition that drives food prices higher, with the number of people that cannot afford an adequate diet increasing more strongly in a 'financial risk-driven' transition. Alongside better economic and social outcomes, the 'policy-facilitated' transition has better environmental outcomes than a 'financial-risk driven one'. Such a transition restores nature intactness to past levels, similar to global outcomes, while a 'financial risk-driven' transition merely stabilizes nature degradation. The 'policy-facilitated' transition also brings the moment the AFOLU sector reaches net zero CO_2 emissions forward by roughly 10 years and carbon sinks almost offset other GHG emissions in the sector by 2050.

A gradual 'policy-facilitated' transition also offers better outcomes for the financial sector who can pro-actively take actions to advance this transition. Our results indicate that an abrupt correction for climate and nature risks led by a financial sector that is 'playing defence' leads to worse results for the real economy and fewer financing opportunities for the financial sector compared to a 'policy-facilitated' transition. Although not modelled explicitly, the more sudden risk repricing would also suggest greater losses overall in the 'financial risk-driven' scenario.[6]

Both policy makers and financiers can take actions that help move away from a disruptive, risk-driven transition to one that is smoother and more orderly. The scenarios in this study present two stark outcomes – neither of which are likely to be fully realised. However, they point to actions that both the public and financial sectors can take to improve economic, social and environmental outcomes, and to the need for prompt action to avoid the accumulation of risks that would make the transition more difficult on all fronts.

Even in the absence of appropriate policy, the financial sector can proactively act to reduce the negative impact of its financing and risk-pricing on GHG emissions and nature loss. The financial sector has several levers it can pull to advance a gradual transition: (i) improving the quality of risk assessments and encouraging disclosure by corporates; (ii) taking action that do not affect capital requirements such as raising awareness about climate and nature risks with borrowers; (iii) gradually integrating these risks into risk management and strategy to avoid the accumulation of risk and sudden repricing; and (iv) deploying more capital to proven NBS and improved agricultural practices that serve as a hedge in the transition.

Nevertheless, only policymakers can create an enabling environment for transition-related financing, including market structures that support sustainable revenue models and appropriate support to de-risk investments with positive systemic spillovers. The types of policy options include (i) well-designed pricing of GHG emissions and nature exploitation (whether through tax or trading systems); (ii) direct support measures for

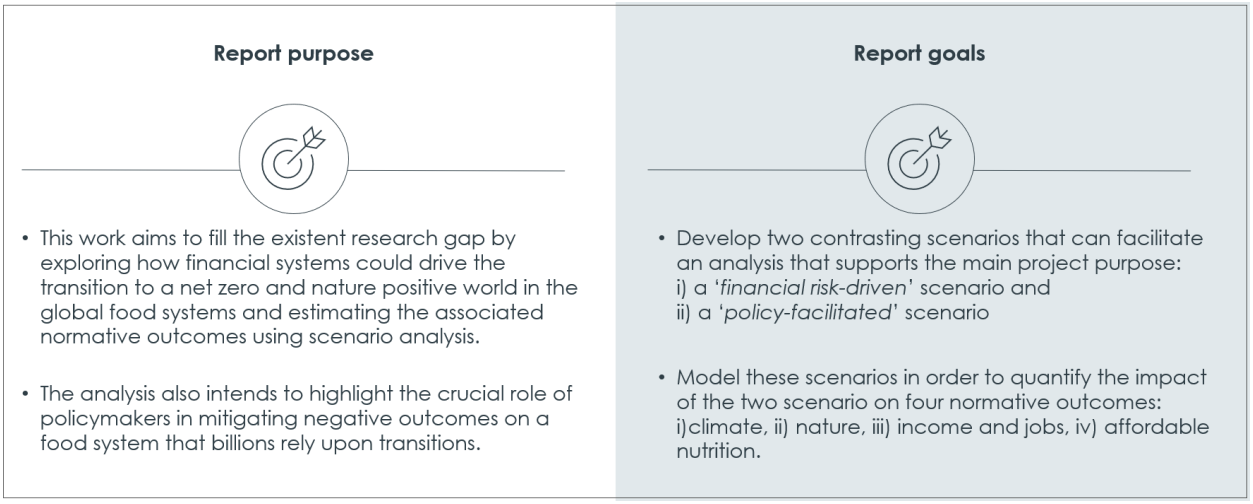
development of NBS or improved agricultural technologies and practices, including for large and small enterprises; (iii) public financing mechanisms to de-risk private finance into emerging sectors and technologies, or with harder-to-finance counterparties; and (iv) social support policies to help mitigate the negative health and nutrition impacts on the most vulnerable populations.

1 Introduction and context

The transition of the food system towards a more sustainable one is inevitable, and the financial system financing the food system plays a key role in this transformation.[7] Although the timing and pathway of the transition is uncertain, the food system in its current form is not sustainable in the long term due to both its contribution and vulnerability to climate change and nature degradation (Section 1.1). The financial sector is increasingly expected (by regulators, shareholders and clients) to factor in the nature and climate risks and impacts associated with its financing activities (Section 1.2). At the same time, the capabilities of the financial sector to quantify climate and nature risks are advancing rapidly, alongside a greater awareness of the materializing climate and nature risks (Section 1.3). The ties between the food and financial systems have grown closer in recent decades, exposing both systems to an abrupt transition (Sections 1.5 and 1.6).

In this study we contrast an abrupt 'financial risk-driven' transition of the food system to a transition facilitated by more orderly public policies ('policy-facilitated' transition) to understand the associated impacts and the role stakeholders can play in mitigating risks to the food system. This section describes the context for these transitions.

Figure 1. The main purpose and goals of this study

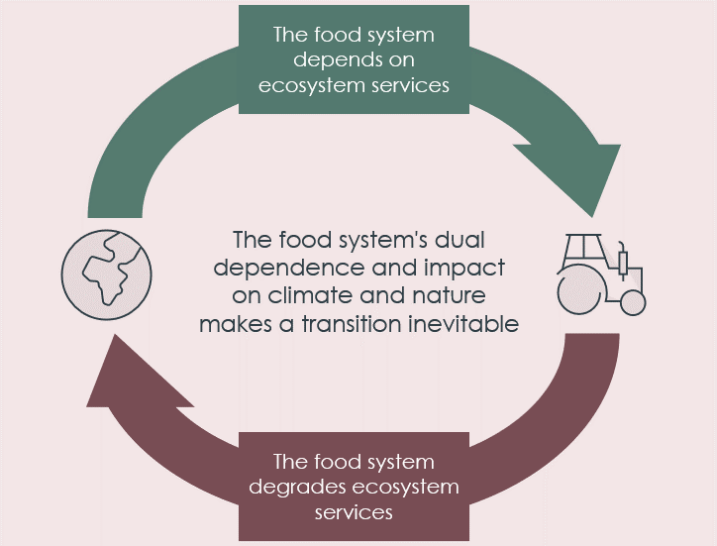


1.1 A TRANSITION IN THE CURRENT FOOD SYSTEM IS INEVITABLE

The food system's negative impact on nature and climate, and the negative feedback on the food system itself, has created pressure for a transition towards higher sustainability.

- The damages caused by the food and agriculture (F&A) sector are estimated to be higher than the sector's total value.[7] These adverse external effects include contributing to climate change and biodiversity loss.
- The sector's impact on climate and nature services increasingly impacts the accessibility and quality of these services, which are necessary to agricultural production. This has knock-on impacts on food security and farmers' livelihoods.

Figure 2. The negative feedback loop between the food system and ecosystem services has created pressure for a transition towards higher sustainability



The food system is a significant contributor to climate change and is crucial in the transition to net zero. The food system generates a third of anthropogenic global greenhouse gas (GHG) emissions,[8,9] a third of which are non-CO_2 GHGs, such as methane from livestock, which are much more potent than CO_2 and difficult to reduce without a significant change in diets.[10] Food system emissions have been growing in the last few decades, mainly due to increasing population and income.[10] Business-as-usual scenarios, accounting for dietary changes and increases in productivity, project further growth of agricultural GHG emissions of 20-30% by 2050.[11,12] Diets shifting away from animal protein can make a difference, particularly in high consumption countries.[81] As the window for keeping temperatures below 1.5 ˚C and avoiding catastrophic consequences closes, the urgency to act pushes governments to set concrete objectives.[13] By May 2022, more than 83 countries responsible for three quarters of global GHG emissions have set net-zero targets by 2050.[14] According to the UNPRI's Inevitable Policy Response (IPR) scenario,

these climate-related pressures are translating into possible sudden policy shifts with potentially disruptive effects on financial risk pricing.[5]

The food system causes significant damage to nature, affecting ecosystem services indispensable to agriculture. Modern agricultural techniques allow generating yields at a rate per hectare higher than ever before.[9] However, this land productivity is often achieved through unsustainable farming practices, such as excessive use of fertilisers and pesticides.[15] Due to these practices and the increasing scale of land clearing for agriculture, the sector became the most significant driver of accelerating biodiversity loss and a major contributor to water scarcity and air, water and soil pollution.[16] At the same time, agriculture depends on ecosystem services, such as water or pollination, as production inputs.[15]

Climate change and biodiversity loss affects the food security of vulnerable communities and the livelihoods of food producers.[9] Food production is the most susceptible sector of the economy to climate change impacts.[9] Environmental degradation has consequences for food production, impacting access to seeds, water availability and quality, pests and diseases and pollination.[9] Additionally, food safety risks in transport and storage can also be exacerbated by the changing climate.[9] These issues not only compromise food security, affecting vulnerable communities the most, but also have an impact on livelihoods of farmers, agricultural workers, and other food producers.

1.2 THE FINANCIAL SECTOR IS UNDER PRESSURE TO RESPOND

Regulators, shareholders and clients increasingly expect the financial system to factor in the nature and climate risks and impacts associated with its financing activities. The pressure on the financial sector comes from various groups of stakeholders.

- Financial regulators, supervisors and central banks increasingly include climate and nature risks in their supervisory mechanisms.
- Corporates have started integrating sustainability into their strategies, causing financial institutions to consider climate and nature-related factors in their risk exposure.
- Consumers are becoming more environmentally conscious in their choices and, together with environmental NGOs, put legal pressure on corporates, governments, and financial institutions.

Financial sector supervisors have been increasingly integrating climate and nature risks into their supervisory mechanisms.[17,18,19] The Bank of England first identified climate change as a potential source of financial instability in 2015,[20] and shortly thereafter, the Financial Stability Board set up the Task Force on Climate-Related Financial Disclosures (TCFD). In 2017, the Network of Central Banks and Supervisors for Greening the Financial System (NGFS) was launched, and 114 central banks and financial supervisors have joined the network ever since, among which several have conducted climate stress test.[6]

Recently, supervisors and central banks have expanded the attention to nature-related risk, and in 2020 the Dutch central bank assessed the domestic financial system's dependency on nature.[21] In 2022, the Taskforce on Nature-related Financial Disclosures (TNFD) published its initial guidance with further recommendations to be released on reporting and acting on nature-related risks.[22,23]

Corporates are increasingly integrating sustainability into strategy as investors' interest in sustainable investments is growing. Climate and nature-related risks dominate the top five global risks concerning world leaders in business.[24] The popularity of Science Based Targets (SBTi) among companies from various sectors, including the food sector, have been growing,[25] as have net zero commitments from financial institutions. Global issuance of sustainable debt (bonds and loans) exceeded a record high USD 1.4 trillion in 2021, almost double the level in 2020.[26] It is expected to increase to USD 1.8 trillion in 2022.

Non-commercial stakeholders, including consumers and NGOs, also pose commercial, reputational and legal risks to those financing unsustainable activities. Consumers worldwide are increasingly concerned about their impact on the environment and their consumption choices have started to reflect that.[27,28,29] Litigation cases related to climate change, usually brought by NGOs and other non-commercial organisations, started in the early 2000s, and by 2020, their number exceeded 200 a year. This number does not include biodiversity-related cases that also are on the rise.[30] Some of them have implications for the food sector. For example, in 2021, in a lawsuit brought by an NGO, Amazônia Protégé, the court ruled that landowners in Brazilian Amazonia are liable for the deforestation of the land they own, even if they purchased the land after it had already been deforested by someone else.[30] Complaints related to financial institutions are particularly common in relation to non-compliance with reporting obligations.[31] Although the climate and nature-related legal risk may not seem material, this may soon change. There is a growing tendency for courts to grant plaintiffs standing and rule in their favour in climate-related litigation.[32]

1.3 A DISORDERLY TRANSITION LED BY THE FINANCIAL SECTOR IS INCREASINGLY POSSIBLE

A greater awareness of the materialising climate and nature risks, alongside advancing capabilities of the financial sector to quantify climate and nature risks, makes an abrupt response by the financial sector increasingly possible.

- The extent of climate change and environmental degradation has become more transparent in recent decades, as have the possible transition risks associated with an 'inevitable policy response'.
- Increased demands for disclosure and improved climate risk analytic tools have also begun to increase financiers' ability to factor in such risks.

- As a result, climate and nature-related risks have become more apparent, with the possibility that financial institutions abruptly reprice these risks as part of a disorderly transition of the food system.

Climate and nature-related risks are increasingly materialising, with implications for financial losses to investors. The 2021 Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report stresses that human-induced climate change is already occurring.[33] The frequency and severity of extreme weather events caused by anthropogenic climate change have increased in the past decade.[33] Such events lead to financial losses. For example, in 2018, droughts, floods and storms in India caused damages estimated at USD 6.1 billion.[34] The economic impact of the 2019-20 Australian wildfires was estimated at AUD 20 billion.[35]

Such events increasingly affect decision-making, raising expectations that policymakers will take action to drive a transition. The UNPRI's Inevitable Policy Response has laid out a detailed forecast of how climate transition risks could unfold as policy action accelerates across the globe.[5] Such a policy response would drive significant impact in the food and agriculture sectors, with implications for companies tied to land-use, and consequently for their investors.

The quality of data on business' climate and nature-related risks and impacts has improved in recent years. The number of scientific studies concerning biodiversity, climate change and its implications has grown in the last few decades.[36,37] The quality of data supporting corporate disclosures of climate and nature-related risks is also improving, as indicated by the growing number of companies reporting according to the TCFD guidelines and disclosing data with Carbon Disclosure Project (CDP) (from 200 in 2003 to 13,000 in 2021).[38] Data quality and availability will increase further, considering the upcoming environmental disclosure regulations in the EU,[39] the US,[40] New Zealand[41] and the UK.

The increasing integration of environmental factors in central banks' stress testing and broader supervision will further boost the quantification of climate and nature-related risks. The recent pressure on the financial sector to manage climate and nature-related risks has mainly focused on financial disclosures (see Section 1.2). However, supervisors have stepped up the requirements in recent years: many central banks, for example, the European Central Bank (ECB) and the Bank of England (BoE), have carried out climate change stress tests and published their results.[6,42]

The combination of accumulated risks, increasing awareness of those risks and improved capacity to quantify those risks could trigger an abrupt response by the financial sector. The increasing evidence base helps transform the uncertain outcomes of environmental degradation into quantified risk.[43] The financial sector could price this risk, leading to a sudden correction and precipitating a disorderly transition. Such a correction is more likely in the absence of appropriate nature degradation mitigation policies and could be triggered by, for example, a major climate event, environmental or financial regulation. The magnitude of such a correction is likely amplified by typical financial market speculative behaviour (see Box 1).

1.4 THE FINANCIAL SECTOR IS EXPOSED TO A DISORDERLY TRANSITION

In recent decades, the ties between the food and financial systems have grown closer, leaving both systems exposed to a disorderly and abrupt transition.

- The provision of financial services has increased with the development of the financial sector and the growing capital intensity of agriculture. This phenomenon is often referred to as 'financial deepening'.
- Agriculture has become an increasingly attractive sector also for non-lending investors, often focused on short-term gains.[44] The links between the different parts of the food and financial systems have grown over all categories of investment (farmland, private equity, venture capital, listed equities, commodities, private debt).
- This deeper and more extensive interrelationship renders both systems exposed to an abrupt and disorderly transition.

The increased interconnectedness between the financial and the food systems has been visible over several investment categories.[7] Investors' interest in F&A, observed especially in the last two decades, was related to growing demand for agricultural products and the relative profitability of agricultural investments compared to other assets.[7] Additionally, after the financial crisis of 2007-08, expansionary monetary policy in the industrialised world increased the inflow of money to financial markets.[7] The increase in investment in F&A was visible in the number of investment funds specialising in this sector, which increased 15 times between 2005 and 2020.[45] In 2020, more than a third of them were focused on farmland, which is low risk and offers relatively high returns.[7] In the last ten years, investors have also become increasingly optimistic about the potential of technological improvements in F&A, which can be observed in the recent growth of venture capital funds related to foodtech and agtech.[46] Additionally, in the last 15 years, the activity of non-commercial investors in agricultural commodity markets has increased, amplifying the volatility of food prices (Box 1).[47,48,49,50]

The tighter links between the financial system and the F&A sector increase the concentration of risk and leave both sectors exposed to higher potential losses. The close ties to the financial sector also have likely contributed to the consolidation in the food sector, as easier access to capital enabled the largest agricultural producers to integrate.[51] Consolidation in the food system translates to a higher concentration risk for the financial sector, rendering them more vulnerable to profitability losses and stranded agricultural assets. The increased ties between the financial sector and the F&A sector also make the latter dependent on access to capital provided by the financial sector and on decisions of private investors, directly impacting their costs and revenues.

Box 1. Financial markets behaviour amplifies commodity-related shocks

In the last 15 years, the volatility of food commodity prices has not always been justified by market fundamentals, and that has caused a heated debate on the role of speculation in food security.[52,53,54] According to some studies, the activity of non-commercial speculators, although it increases market liquidity, may amplify price volatility, especially when speculators with expectations disconnected from fundamentals engage in herd behaviour.[47]

Since 2007, several food crises were possibly aggravated by speculative activity, even though their root causes were market fundamentals (Figure 3). We have reviewed four examples of such crises:

2007-08 and 2010-12 food price crises

Supply shocks related to droughts, floods, and high energy prices hit food sector already pressured by increasing demand, including for biofuel subsidised by the EU and the U.S. [48,52,53,55] Export controls implemented in 33 countries further added to the upward pressure on prices. At the same time, as the economic downturn weakened bond and equity markets, more speculative investors sought returns in agriculture commodity financial products, amplifying price volatility on food markets.[47,48,49,50]

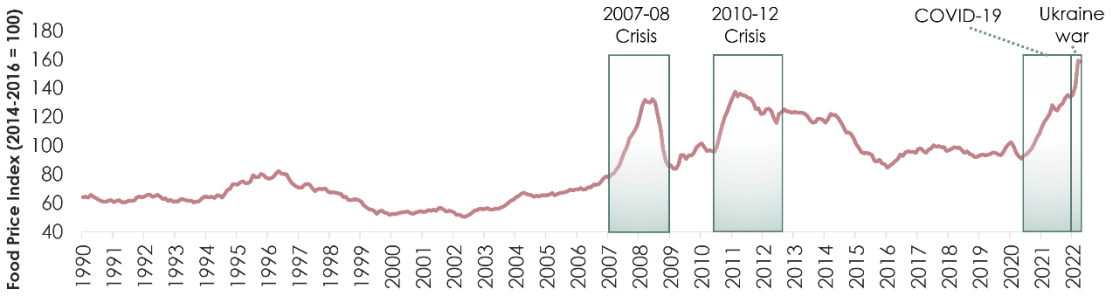
COVID-19

Expansive fiscal policies in response to the COVID-19 crisis, disruptions of food chains and stockpiling caused food price increases in 2020.[56] This was despite record low energy prices. It is not clear to what extent speculative activity has contributed to this price shock.

War in Ukraine

The war between two large food producers, continued food shortages and high prices after the global pandemic, oil prices increase, and food export bans were the root causes of this food price increase. The conflict put pressure on the prices of several commodities, including sunflower and wheat.[57] The UN anticipated food speculation as a result.[58] There are no studies that examine the causes of this crisis in detail. However, economic commentary has pointed to the activity of speculators as exacerbating current high prices.[59,60]

Figure 3. Global food price volatility has increased since the 2007 crisis



Source: Vivid Economics based on FAOSTAT data (accessed 13 May 2022)

1.5 A SMOOTH TRANSITION IS STILL POSSIBLE

Previous research points to various ways in which policymakers can facilitate a smoother transition:

- A number of policies are available to support a shift in economic activity and capital allocation.
- Early and credible policy action is generally expected to make the shift smoother and less disruptive.

A body of research suggests a set of credible policy options. These include better price for GHG emissions and nature loss, and options that support investments in, and economic adjustment toward sustainable activities, such as nature-based solutions and improved agricultural production practices. Recent estimates show that such a transition may require increasing the yearly global spending on physical assets within the energy and land-use systems by 60% between 2021 and 2050.[61] To date, only limited-scale NBS projects have managed to effectively redirect investment towards the transition of AFOLU into a nature and climate-positive sector. Greater intervention by policymakers is therefore likely to be needed to facilitate this transition. Importantly, considering the size of investments required for this transition, it is essential to channel both public and private flows in the right direction.

A smooth transition to net zero is still possible, if appropriate and timely policies are introduced.[61] There is a body of analysis showing that a transition that is delayed or does not involve appropriate efforts could result in a 'hard landing', with much higher transition costs and more severe consequences of environmental degradation.[61,62] Such a transition would also have knock-on impacts on the economy more broadly, affecting vulnerable households the most, and potentially creating a consumer backlash that would further slow the transition down.[61,62]

1.6 GOAL OF THIS STUDY

This report contrasts a financial risk-driven disorderly food system transition with a transition facilitated by appropriate policies, attempting to assess the impact of these policies on environmental, economic, and social outcomes. This is the first report to explore a transition of the food system driven by the financial sector, and to examine its consequences. The study aims to answer the following questions:

- What would the outcome of a disorderly transition driven by the financial sector be, in terms of climate, nature, economic outcomes and social outcomes?
- How much would this outcome improve if the transition was managed with appropriate policies?
- How can the public and private sectors operate to unlock a better transition pathway and avoid some of the worst impacts of the transition?

- How can the policymakers mitigate bad outcomes that cannot be avoided?
- How does the private sector benefit from pricing-in climate and nature-related risks and benefits in their activities?

We attempt to answer these questions by designing plausible scenarios and modelling them using an approach outlined in Section 2. We first answer these questions for the world (Section 3), and then focus on the Brazilian economy (Section 4).

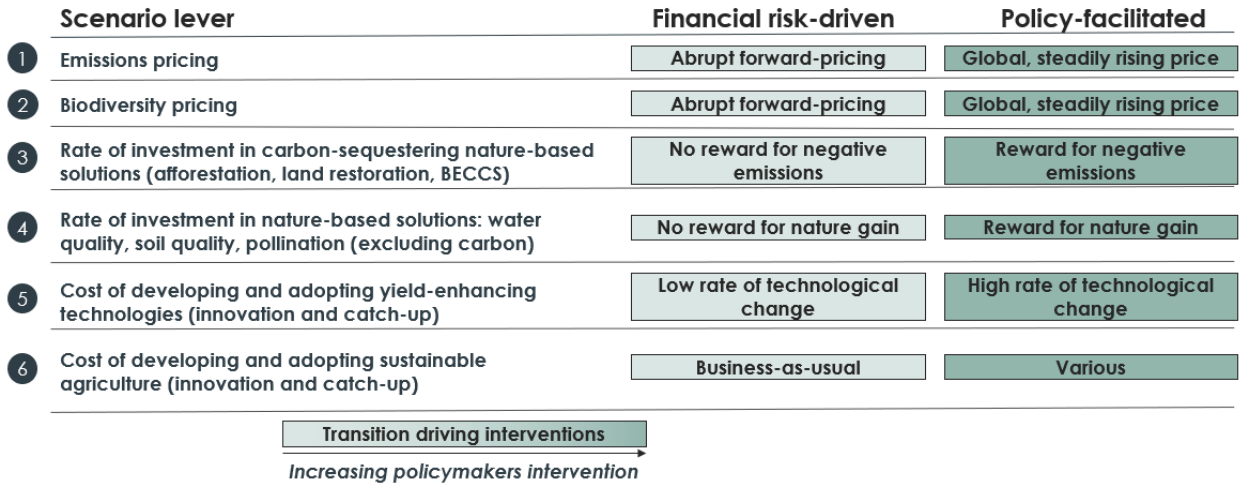
2 A 'financial risk-driven' disorderly transition and a 'policy-facilitated' orderly one

In the absence of appropriate policy to mitigate GHG emissions and nature loss, an abrupt response by the financial sector to correct for accumulating climate and nature risks is increasingly possible, while prompt action by policymakers could facilitate a smoother and more orderly transition. This section introduces these two scenarios:

- a **'financial risk-driven' scenario.** As outlined in Section 1.3, and examined by the UNPRI's Inevitable Policy Response,[5] the financial sector is more likely to price in climate and nature risks as awareness of these risks grows, as they begin to materialise, and as data and risk assessment methods improve. Taken together, the financial system response could be swift in such a situation (Section 2.1).
- a **'policy-facilitated' scenario.** In contrast, policymakers can act promptly to mitigate climate change and reverse nature degradation, thereby facilitating a smooth and orderly transition. Such a scenario would create a transparent and predictable regulatory environment in which a sharp response by the financial sector is less likely (Section 2.2).

We model these scenarios relying on a partial equilibrium model of the global land-use system MAgPIE[63] (see Annex 2 for methodology).

Figure 4. The levers differ across scenarios according to the envisaged response by the financial sector or policymakers



Source: Vivid Economics

2.1 A FINANCIAL SECTOR THAT PRICES IN NATURE AND CLIMATE RISKS

When the financial sector initially recognises a risk – like nature and climate-related risk – it will generally adjust immediately, with sharper adjustments possible where there remains high uncertainty about the full extent of the risk.

- To compensate for the new risk, all investors in affected businesses will demand higher returns or reallocate their capital. Lenders will tighten financial conditions for new borrowers whose businesses are affected. Traders will react abruptly and increase price volatility in the stock and commodity markets.
- The potential reallocation of capital away from the F&A sector may hurt the real economy and could prevent sufficient investment in sustainable F&A needed for a smooth transition.

The 'financial risk-driven' scenario explores this possible future by modelling the impacts of a sudden shift in the cost placed on activities contributing to climate change or nature loss, and then the pricing of financial assets associated with such activities.

To shield themselves from nature and climate risks, financial institutions are likely to tighten financial conditions and divest from the riskiest activities, leaving some assets stranded in the process. Higher returns must compensate higher risks. Therefore, investors will increase their profit requirements for investments with higher climate and nature risks. Investments that do not meet these requirements will see a lower influx of capital. For the riskiest activities, such as projects involving deforestation, this could lead to divestment, and that may result in stranded assets. This has been observed in the energy sector in the EU, where government policy to phase out coal by 2030 has led to divestment by the financial sector (see Box 2). Studies predict similar consequences for oil and gas assets expected to become stranded if the world suddenly moves to limit global warming to 1.5˚C.[64] This could also happen in the F&A sector.

Repricing of climate and nature risk will contribute to the reallocation of capital towards less risky activities, and corresponding adjustments by their clients. The financial sector can price in nature in several ways: by incorporating the risks in borrowers' credit ratings, by increasing the interest rates on affected loans, or by supporting their clients in mitigating and adapting to these risks.[65] Companies in risker activities will see the cost of capital increase. In the short run, these companies may pass the higher costs on to consumers or absorb them, depending on the market characteristics and their return margins. In the longer run, affected companies may want to limit their exposure to climate and nature-related risks for many reasons, including reducing their cost of capital. They can do it in cooperation with the lenders, for example by committing to limiting deforestation or implementing a decarbonisation plan. Similarly, financiers can reduce the cost of lending for activities not affected by climate or nature risk. Overall, the profitability and liquidity of businesses will be affected, and the capital will be redirected towards activities with lower climate and nature risks.

The response of financial agents and traders will likely lead to an abrupt reaction in financial markets that causes high food price volatility and a re-evaluation of enterprise values. While the reaction of lenders and direct investors may take time, changes in financial markets are likely to be swift. In the short term, financial trading in soft commodities and related financial instruments will lead to higher volatility of food prices and larger price corrections justified by the anticipated nature and climate risks (see Box 2). This could affect the value of companies in riskier activities, or F&A companies overall. Traders could benefit from this volatility in the short-run, while the longer-run impact of trading activity on food prices and company values will depend on underlying climate and nature risks and the elasticity of supply (driven by constraints on land use, technological progress, and financing constraints) and demand (driven by substitution effects).

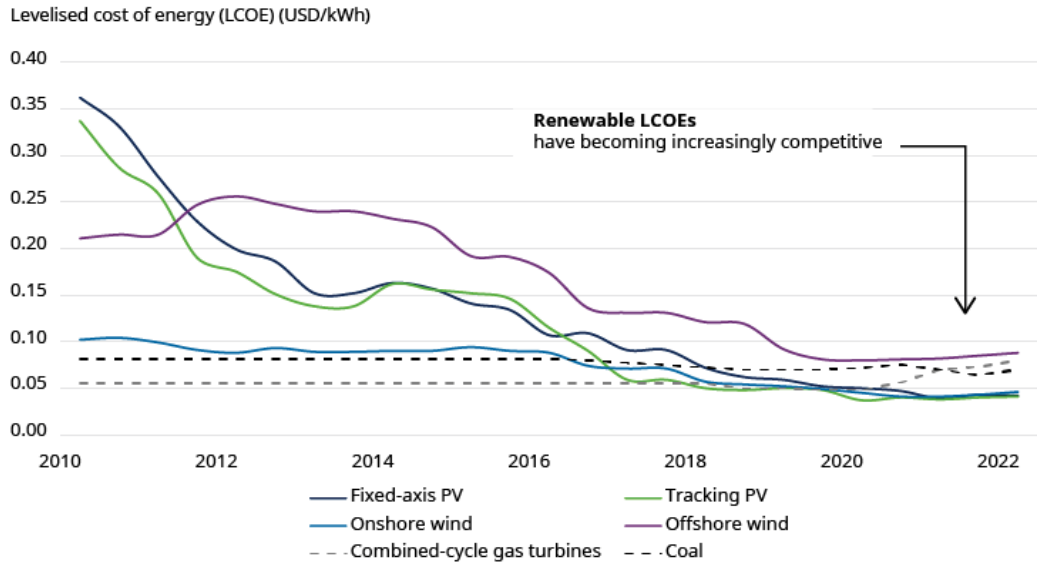
The rapid reallocation of capital away from unsustainable F&A activities will have a negative effect on the real economy and does not guarantee sufficient investment in sustainable F&A. Among other possible impacts, the rapid reallocation of capital may lead to financial losses for less sustainable producers and food shortages (see Section 3). The outflow of capital from the least sustainable agricultural activities does not guarantee investment in climate and nature-positive agriculture activities. In the case of the European coal divestment, investors needed additional policy incentives to increase investments in renewable energy (Box 2).[66]

Box 2. Financial sector in the EU divested from coal anticipating policy change

A reliable and transparent regulatory environment matters for the efficiency of future climate policies. According to a Potsdam Institute for Climate Impact Research (PIK) study, investors start pulling their money out of the coal power sector around ten years before carbon pricing policies were introduced. This is largely thanks to the transparent long-term planning of policymakers and partly due to the long-term horizon of energy projects. This divestment reduces emissions by between 5 to 20% (depending on the strength of the climate policy) before the climate policy is even implemented.[67]

A drop in investors' interest in coal does not automatically translate into investment in renewable energy, until it becomes a profitable alternative. In Europe, a gradual drop in investors' interest in the dirtiest fossil fuel could be noticed since the early 2000s. However, this loss of attractiveness of coal projects for investors was not enough to trigger serious private investment in, at the time, relatively expensive and risky renewable energy sources (RES) projects. To grow, RES needed to become a profitable alternative to other power generation sources (Figure 5).[68]

Figure 5. Global levelized cost of electricity (excluding subsidies) from RES has strongly decreased in the last decade[69]



Subsidies introduced to increase profitability of RES for investors contributed to technological improvement and reducing RES' cost. Since the early 2000s, many countries, including the EU members, the US, China, India, and Japan, gradually introduced support schemes improving the profitability of renewable energy projects for investors, which soon led to mushrooming of RES projects.[70,71] Largely thanks to this support, in the last decade, the global cost of all renewable technologies has decreased significantly. Importantly, unexpected changes in renewables support schemes in some European governments (such as Spain, Italy, Poland, and Romania) had financial consequences for investors and led to costly legal disputes between the affected investors and the governments. This further strengthens the point on the importance of trust, transparency and information in policymaking and managing legal risks of the transition.

Reflecting such a possible future for the food and agricultural system, the 'financial risk-driven' scenario models the responses described above and is presented in detail in Annex 2. The 'financial risk-driven' scenario models the impacts of a sudden shift in the cost placed on activities contributing to climate change or nature loss. Such a rapid realisation of the costs would in turn lead to the re-pricing of financial assets associated with such activities by the financial sector. More details on the specific drivers and modelling of the 'financial risk-driven' scenarios are provided in Annex 2 and the outcomes are illustrated in Sections 3 (global outcomes) and 4 (outcomes for Brazil).

2.2 POLICYMAKERS CAN INTERVENE TO FACILITATE A SMOOTH TRANSITION

Prompt actions by policymakers to mitigate climate and reverse nature degradation in the food system can facilitate a smooth transition and incentivise financial sector flows in the right direction. Interventions can focus on incentivising investments by the financial sector in various areas, including:[72]

1) increasing the emission efficiency of agricultural production;
2) avoiding land expansion or managing it and restoring marginal lands to natural ecosystems;
3) implementing known agricultural management practices that mitigate emissions and biodiversity loss; and
4) supporting innovations to increase opportunities.

The 'Policy-facilitated' scenario explores this possible future by modelling how such interventions would change the risks and opportunities in a more gradual and transparent way, with the consequent smoother reallocation of capital.

Action by policymakers can radically decrease the food system's GHG emissions and reduce damage to nature, while at the same time, significantly increase food production for the growing population.[72] Interventions can also stimulate private finance to support such a transition by de-risking climate and nature-positive investments and creating an enabling environment for them, through, for example, creating markets for carbon offsetting.[7] To ensure the right reaction of the financial sector, it is important that policies are credible, transparent, and well-communicated (Box 2).[73] We also note that in practice, effective policymaking requires the support of various stakeholders such the private sector and civil society.

The transition-driving interventions that we consider in the 'policy-facilitated' scenario include:

- **Gradually introducing a price on GHG emissions and biodiversity loss and communicating it clearly.**[74] Pricing negative externalities related to climate and nature can direct financial flows towards more sustainable activities. Gradual introduction of such pricing helps prevent an abrupt reaction of the financial sector. It is equally important that policymakers coordinate to enact a globally consistent pricing policy and pro-actively provide financial markets with reliable and predictable information regarding envisaged transition paths.
- **Stimulating investment in biodiversity restoration and nature-positive infrastructure.** As indicated in Box 2, punishing environmental damage does not necessarily lead to financing of nature-positive solutions. To support such investments beyond voluntary offset markets, policymakers can create and develop the conditions for nature markets, including offset markets offering rewards for negative emissions and biodiversity offsets.[75,76] Efficient offset markets provide viable

long-term investments, have transparent and straightforward rules, and ensure social sustainability by making local communities net beneficiaries of the policies.[76]

- **Creating incentives for developing and adopting technologies that enhance yield or improve the sustainability of agricultural production.** Interventions can achieve this through subsidies for R&D or introducing sustainable technologies,[72] by protecting intellectual property and funding training programmes. Mainstreaming innovations and traditional sustainable farming practices can be done, for example, through blended finance schemes,[7] training and agricultural extension services.[77] Additionally, policymakers can condition subsidies for food producers on the implementation of sustainable practices and protecting natural areas. in cases where expansion is inevitable, policymakers can develop land-use plans to target their support for agricultural development where emissions and biodiversity impacts will be lowest.[72]

All these interventions can help facilitate a smooth and orderly transition. An abrupt financial sector response is less likely in such a situation, given the stable and predictable regulatory environment and the fact that the interventions reduce climate and nature risk across the board.

While the 'policy-facilitated' scenario may be ambitious, it allows an interrogation of policies key to guiding the transition, and can therefore better guide policymaking. In practice, implementation of these policies requires strong institutions and significant public spending. A weak economic position, inefficient institutions and political tensions may hamper a 'policy-facilitated' transition in some countries. An appreciation of the investment required helps interpret these results.

More details on the specific drivers and modelling of the two scenarios described above are provided in Annex 3Annex 2 and the outcomes are illustrated in Sections 3 (global outcomes) and 4 (outcomes for Brazil). Annex 2

2.3 POLICYMAKERS CAN INTERVENE TO ALLEVIATE NORMATIVE IMPACTS

In both scenarios, policymakers can implement interventions that alleviate negative normative impacts of the transition and thereby facilitate a just transition. Such policies could focus on supporting vulnerable consumers and producers most affected by the economic consequences of the transition, and include:

- **Support for vulnerable producers.** For farmers (especially smallholders) who have difficulties keeping up with the sector's transition, this support may take the form of blended finance schemes, improving land tenure security and promoting farmers' associations and agricultural cooperatives.[78,79] Additionally, upskilling may tackle the lack of access to relevant knowledge, and retraining may be helpful if carbon sequestration or biodiversity restoration offer better work opportunities than farming.
- **Support for vulnerable consumers.** Such interventions improve food security through, for example, cash transfers, community kitchens, surplus food hubs (limiting food waste) and support for own-needs urban agriculture.[80]

In Sections 3 (global) and 4 (Brazil), we discuss how these policies could be used to alleviate impacts of the transition of the food system.

2.4 HOW AND WHY THESE SCENARIOS DIFFER FROM COMMONLY USED CLIMATE SCENARIOS

This study is the first to consider a financial response that drives the transition towards net zero and the reversal of nature degradation by 2050. The drivers that we consider for this scenario have been used before in other scenarios such as the Inevitable Policy Response and the NGFS scenarios.[5,3] However, the way this study implements them is new. An abrupt emissions and nature price increase in 2025 are the only drivers of the 'financial-risk driven' scenario. The NGFS also considers an abrupt price increase in the Divergent net zero and the Delayed transition scenarios, but nature is not included, and these scenarios are driven by a multitude of factors.

The 'policy-facilitated' scenario resembles existing studies but has a slightly different parametrisation. Existing studies include many scenarios that see policy pushing the world to net zero and reversing nature degradation.[3,5,15,81] Most of these scenarios consider pricing of emissions and technological progress. Some even consider rewards for carbon sequestration and other nature-based solutions. The IPR Forecasted Policy Scenario comes closest to our set up with much more detailed exploration of the 'inevitable' policy shift that might drive a sudden risk repricing, but it does not consider a price on nature.

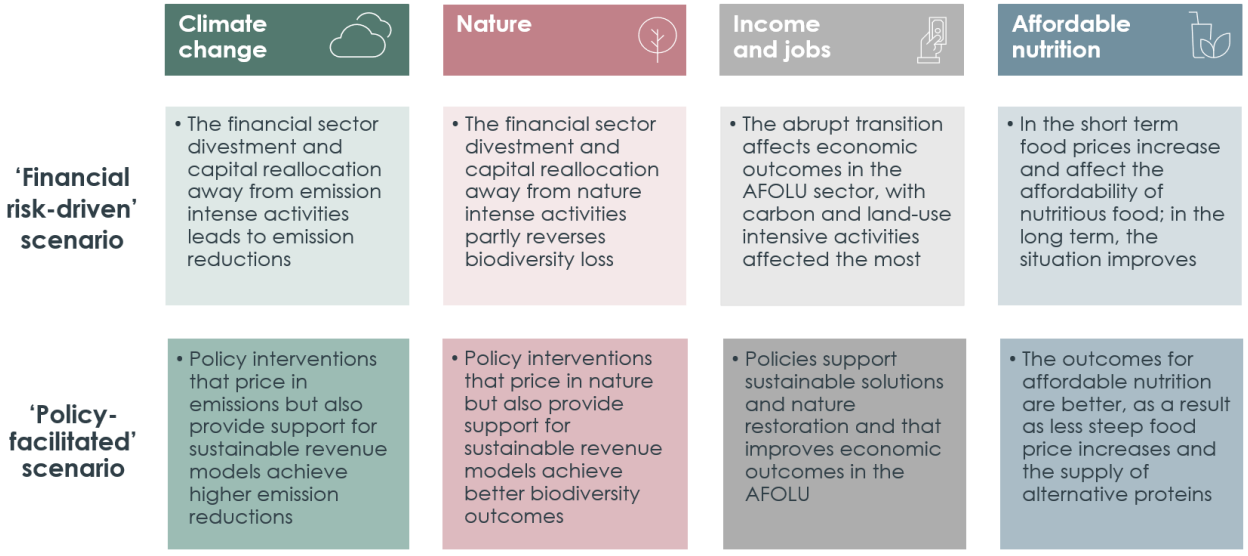
Previous studies generally compare a 'policy-facilitated' scenario to some baseline scenario. Most of the studies include a 'business-as-usual' or 'current policies' scenario as a baseline. They then compare a specific policy action scenario to the baseline in which neither the financial sector nor policymakers drive a transition to net zero and to a reversal of nature degradation. While such comparisons can be insightful, it is not clear why such 'BAU' or 'current policies' represent the correct counterfactual, and this study helps explore different prospective futures.

3 The impact on the global food system

A 'policy-facilitated' transition leads to better economic, social, and environmental outcomes than a 'financial risk-driven' transition. This section compares the results of the 'financial risk-driven' scenario and the 'policy-facilitated' scenario to draw out how the two would affect the food and agricultural systems differently. We present the effects of the transition in both scenarios using four normative outcomes:

- Climate change,
- Nature,
- Income and jobs,
- Affordable nutrition.

Figure 6. Modelling results are compared across four normative outcomes



Source: Vivid Economics

3.1 CLIMATE CHANGE

Although the cost of emissions reaches the same level in 2050 in the two scenarios, the GHG emission outcomes are better in the 'policy-facilitated' scenario. This difference is driven by the following assumptions in the 'policy-facilitated' scenario:

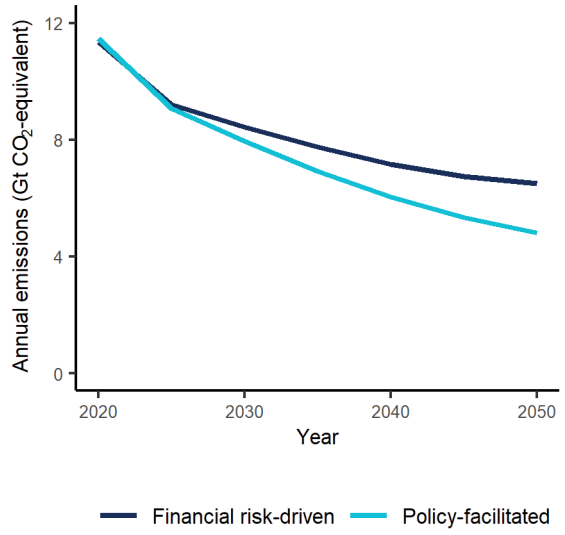
- Policies incentivising the development and the adoption of yield- and sustainability-enhancing technologies.
- Policies stimulating nature restoration, including rewards for high-biodiversity woodlands contributing to removing carbon from the atmosphere.

In both scenarios, the price on emissions reaches the same level in 2050, but emission reduction outcomes are better in the 'policy-facilitated' scenario. In the 'financial risk-driven' scenario the emissions price rises more abruptly than in the 'policy-facilitated' scenario, but the two scenarios converge by 2050. However, results indicate that a 'policy-facilitated' transition results in lower cumulative emissions than the 'financial risk-driven' transition. By 2050, emissions in the 'policy-facilitated' decrease by 58% relative to 2020 levels, compared to 42% in the 'financial risk-driven' scenario.

In the 'financial risk-driven' scenario, the financial sector limits emissions by rapidly reallocating capital away from the most carbon-intensive activities but does not support investment in natural carbon sinks. In the 'financial risk-driven' scenario, in response to climate and nature-related risks, the financial sector diverts capital away from the most emissions and nature-intensive businesses (see Section 2.1). The capital reallocation leaves producers with increased costs, limited financing and pressure to decrease their environmental impact. As deforestation is reduced, AFOLU net CO_2 emissions decrease, reaching CO_2 net zero in 2050 (Figure 8). The outflow of capital from the least sustainable AFOLU activities does not guarantee investment in climate and nature-positive activities, such as restoration of natural ecosystems, unless they offer a good return. As a result, restoration of ecosystems storing carbon in the 'financial risk-driven' scenario is limited.

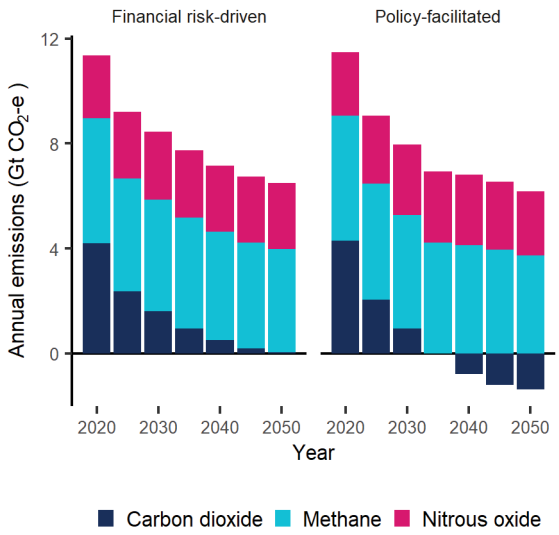
The 'policy-facilitated' transition promoting restoration of natural ecosystems curbs emissions more efficiently than the 'financial risk-driven' transition. The 'policy-facilitated' scenario assumes the introduction of policies incentivising the development and adoption of the yield- and sustainability-enhancing technologies. In this scenario, GHG emissions pricing is announced in advance and gradually introduced, and there is clear communication on expected price trajectories. Stimulated by these policies, AFOLU companies reduce the emissions they generate (Figure 7). Additionally, the 'policy-facilitated' scenario assumes incentives stimulating nature restoration and offset markets offering rewards for carbon offsetting. These policies cause an increase in forest area, replacing agricultural land. Thanks to restoration of natural ecosystems, the 'policy-facilitated' transition achieves CO_2 net-zero roughly 10-15 years before the 'financial risk-driven' transition does (Figure 8).

Figure 7. Annual AFOLU GHG emissions



Source: Vivid Economics

Figure 8. Annual AFOLU emissions by GHG



Source: Vivid Economics

3.2 NATURE

In 2050, the cost of nature loss in both scenarios is the same, however, due to nature restoration efforts, nature outcomes are better in the 'policy-facilitated' scenario.

- Both scenarios restore the level of biodiversity to past levels.
- In the 'financial risk-driven' scenario, the financial sector limits nature degradation by reallocating capital away from the most unsustainable activities.
- The 'policy-facilitated' transition not only makes biodiversity loss costly to AFOLU producers, but also rewards nature restoration.

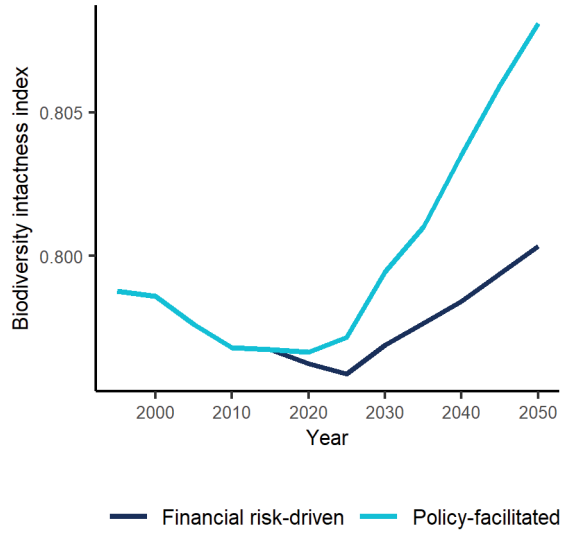
Both scenarios lead to the same price on nature loss in 2050, and that limits nature degradation caused by the AFOLU sector. In the 'financial risk-driven' scenario the price of biodiversity loss grows more steeply than in the 'policy-facilitated' scenario at the beginning of the period. Nevertheless, results indicate that a 'policy-facilitated' transition leads to better biodiversity outcomes. This difference results from policies incentivising nature restoration in the 'policy-facilitated' scenario such as stacked payments for carbon and biodiversity.

In the 'financial risk-driven' scenario the financial sector limits nature degradation by reallocating capital away from harmful activities but does not support investment in nature restoration. In the 'financial risk-driven' scenario, the rapid reallocation of capital toward more sustainable businesses reduces nature degradation and allows biodiversity to recover (Figure 9). However, as mentioned earlier, the capital reallocation does not guarantee investment in restoration of natural ecosystems. As in the 'financial risk-driven'

scenario such activities are risky and do not offer sufficient return, economic activity related to ecosystem restoration is limited.

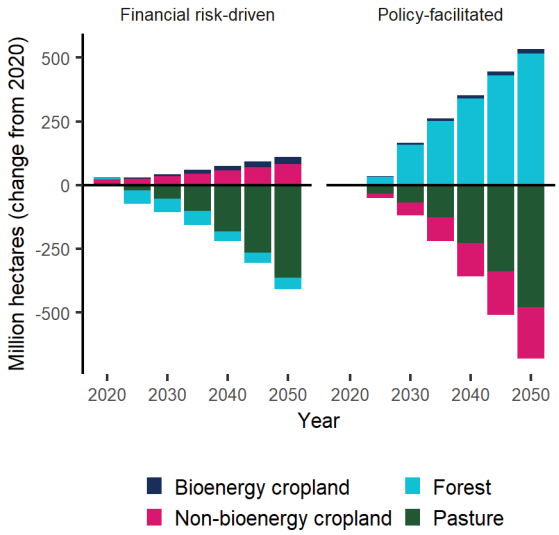
The 'policy-facilitated' transition promoting restoration of natural ecosystems improves biodiversity more efficiently than the 'financial risk-driven' transition. The 'policy-facilitated' scenario not only makes biodiversity loss costly, but also rewards its recovery. For example, the scenario allows for stacked carbon and biodiversity payments to incentivise planting of high-biodiversity woodlands. These policies cause an increase in forest area, replacing agricultural land (Figure 10). In terms of the biodiversity intactness index (BII), a widely accepted measure of biodiversity,[4] the 'policy-facilitated' scenario is at least 10 years ahead of the 'financial risk-driven' scenario in biodiversity restoration. Specifically, the 'policy-facilitated' scenario restores 1995 levels of biodiversity by 2030; the 'financial risk-driven' scenario reaches 1995 levels in the2040s.

Figure 9. Biodiversity intactness index



Source: Vivid Economics

Figure 10. Agricultural and forest land (change from 2020)



Source: Vivid Economics

3.3 INCOME AND JOBS

A 'financial risk-driven' transition comes at an economic cost, while a 'policy-facilitated' one maintains economic growth in the AFOLU sector and protects roughly 78 million jobs.

- Sectoral GVA is 17% (USD 575 billions) higher in the 'policy-facilitated' scenario compared to the 'financial-risk driven' in 2050, and direct employment is 9% higher.
- The differences are mainly driven by (i) Business and job opportunities associated with ecosystem restoration and climate mitigation spending in the 'policy-

facilitated' scenario and (ii)higher agricultural productivity growth in the 'policy-facilitated' scenario than in the 'financial risk-driven' scenario.

A 'financial risk-driven' transition stunts economic growth in the AFOLU sector and employment decreases over the time horizon. In the medium to long term, conflicting trends in productivity and new environmental costs results in sluggish growth in the AFOLU sector, with GVA falling 3% below 2020 levels by 2050 in the 'financial-risk' driven scenario (Figure 11). This comes primarily from declining value of forestry activities and food prices decreasing after 2035. Direct employment slowly decreases over the same period and ends up almost 10% lower than in 2020 (Figure 13**Figure 14**). Reductions in AFOLU employment are mainly due to the increased productivity of meat production and loss of managed forest activity.

The economic outcomes may be even worse in the short term if financial flows to the AFOLU sector dry up very rapidly in combination with other crises. While this analysis captures the effects of rapidly growing risk to food producers, we do not capture the full set of possible negative short-term effects, particularly in combination with other sources of risk. Should the risk profile of AFOLU companies owing to nature and climate risk be combined with more cyclical shocks to the F&A sector, or with a broader financial system shock, this could compound panic with financiers and lead to even more negative food supply shocks that further exacerbate food shortages and affect the entire economy. Box 1 above already laid out some of the existing cyclical effects that might be layered onto our analysis, and other research has also demonstrated how panic in the financial sector is strongly linked to broader economic contraction through decreased credit flows[82], with implications for the agricultural sector[83,84]. It is important to recognize that the 'financial-risk driven' transition could potentially interact with these broader sources of risk with negative amplification of the results shown here. While in contrast, the 'policy-facilitated' transition would be expected to build better underlying resilience.

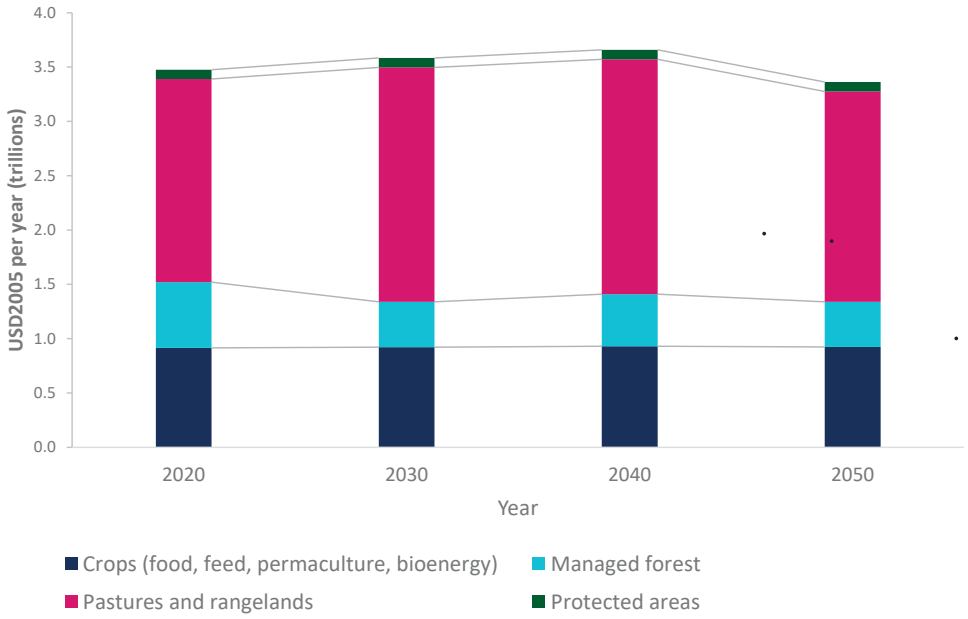
The 'policy-facilitated' scenario offers wider adjustment options to the AFOLU sector, and more time to adjust to risk pricing, resulting in better outcomes primarily through higher land productivity and greater expansion of ecosystem restoration activities. In both scenarios, AFOLU sector producers bear the cost of emissions and biodiversity pricing, as well as undertake investments to improve their sustainability. In the 'financial risk-driven' scenario, the financial sector rapidly prices in climate and nature-related risks, divesting from the most unsustainable activities and increasing the cost of capital for remaining producers (see Section 2.1). In the 'policy-facilitated' scenario, producers pay the emissions and biodiversity price associated with their environmental impact. In this scenario, however, appropriate policies enable the food and financial sectors to anticipate the transition, invest in sustainability and productivity and gradually reallocate financing, thereby limiting the economic impact of the transition. Additionally, the 'policy-facilitated' transition assumes policies incentivising nature restoration and carbon sequestration, which support the creation of new businesses and jobs. By 2050, the 'policy-facilitated' scenario shows 17% (USD 575 billions) higher GVA than the 'financial risk-driven' scenario

(Figure 11, Figure 12) It also protects 78 million jobs, a 9% higher direct employment level then in the 'financial-risk driven' scenario (Figure 13, Figure 14).

In the 'policy-facilitated' scenario, a gradual transition that stimulates investment in productivity improves the economic outcomes of the transition. In the 'policy-facilitated' scenario, well-communicated GHG emissions and biodiversity price trajectories and policies decreasing the risk and cost of the transition (Section 2.2) incentivise AFOLU companies and the financial sector to invest in sustainability and yield-enhancing technologies. Therefore, the short-term adjustment of the financial sector, including the reallocation of capital, is less intense and more gradual than in the 'financial risk-driven' scenario, making the negative food supply shock less likely. Additionally, as a result of the incentivised investment in yield-enhancing, agricultural land productivity increases much faster than in the 'financial risk-driven' scenario (Figure 29). This allows to produce more agricultural output from the same land area and puts downward pressure on land prices and production costs (Figure 28).

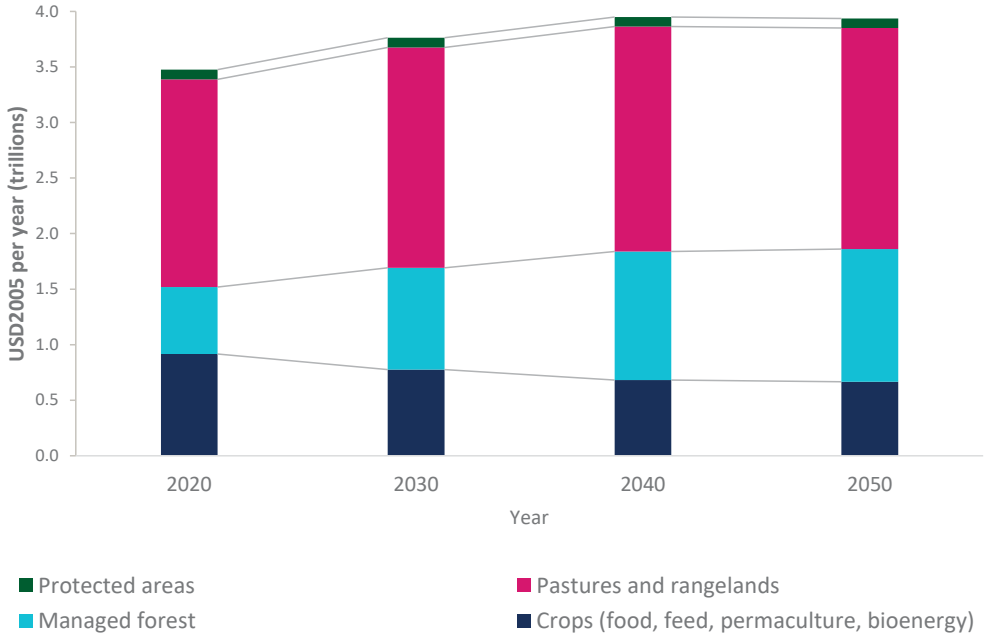
Nature restoration activities promoted in the 'policy-facilitated' scenario additionally improve economic outcomes in this scenario. The increase in land productivity in the 'policy-facilitated' scenario coincides with increased competition for land induced by policies stimulating investment in biodiversity restoration. Managed forests replace some of the pastureland and cropland. As a result, agricultural GVA and employment decrease. However, the growing forestry activities largely compensate for this negative change. Over this time horizon the policy-facilitated scenario sustains GVA growth and jobs stabilise, with 13% and -1% change relative to 2020 respectively (Figure 12, Figure 14).

Figure 11. AFOLU Gross Value Added by land class – Financial risk-driven



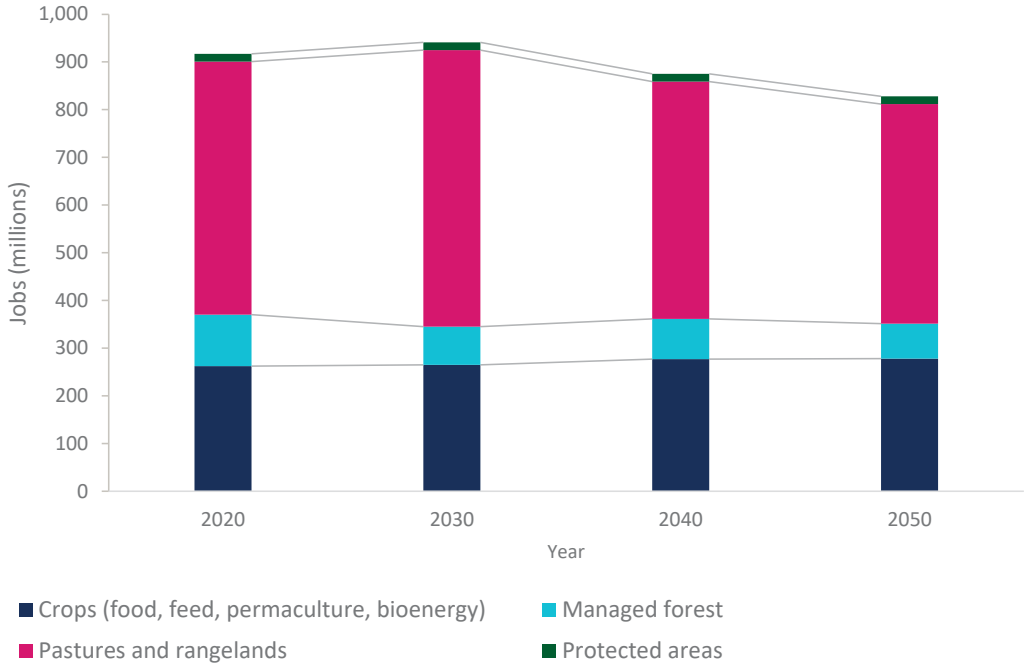
Source: Vivid Economics

Figure 12. AFOLU Gross Value Added by land class – Policy-facilitated



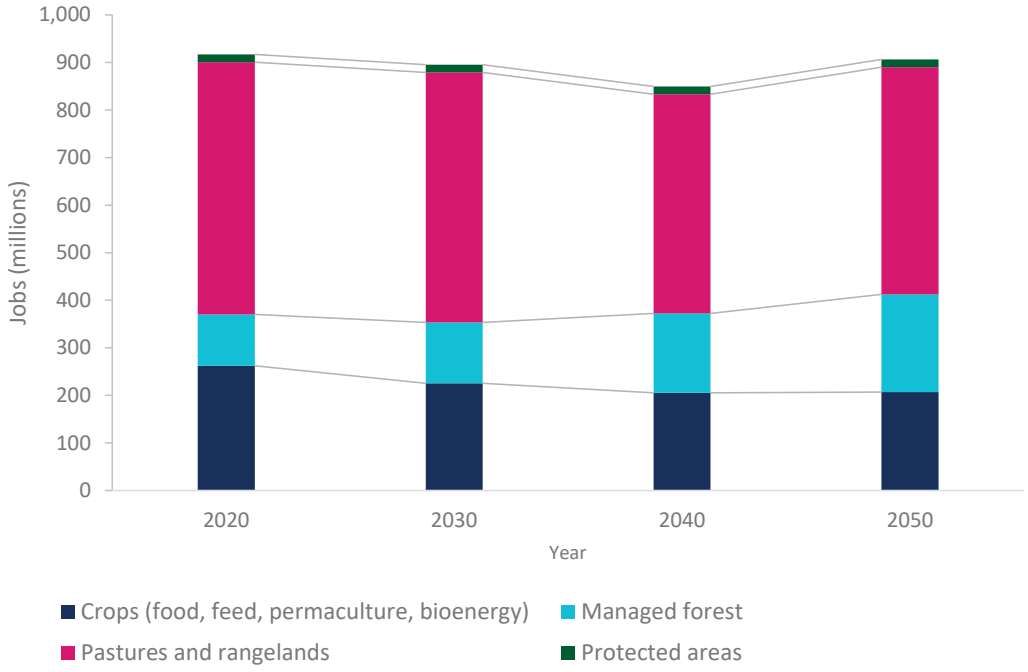
Source: Vivid Economics

Figure 13. AFOLU employment by land class – Financial risk-driven



Source: Vivid Economics

Figure 14. AFOLU employment by land class – Policy-facilitated



Source: Vivid Economics

3.4 AFFORDABLE NUTRITION

Higher food prices in the 'financial risk-driven' scenario drive costs of nutrition higher than in the 'policy-facilitated' transition.

- In both scenarios, due to the growing cost of emissions and biodiversity loss, food prices increase affecting nutrition affordability in the short-term.
- In the 'policy-facilitated' scenario, policies stimulating investment in sustainability and yield-enhancing activities limit the price increase. Moreover, the scenario supports investment in alternative protein which further improve nutrition outcomes.
- The difference between the two scenarios peaks in 2040 when in the 'financial - risk driven' scenario roughly 3.3 million more people cannot afford a sufficient diet compared to the 'policy-facilitated'.

In the 'financial risk-driven' scenario, a rapid increase in the cost of capital causes a short-term increase in food prices. In this scenario, the financial sector suddenly prices in climate and nature-related risks, rapidly increasing the cost of capital for the AFOLU sector. This increase in costs means that the producers need to either:

- (i) increase prices or, if that is not possible due to the market conditions (competition and/or high price elasticity),
- (ii) accept lower profit or discontinue production.

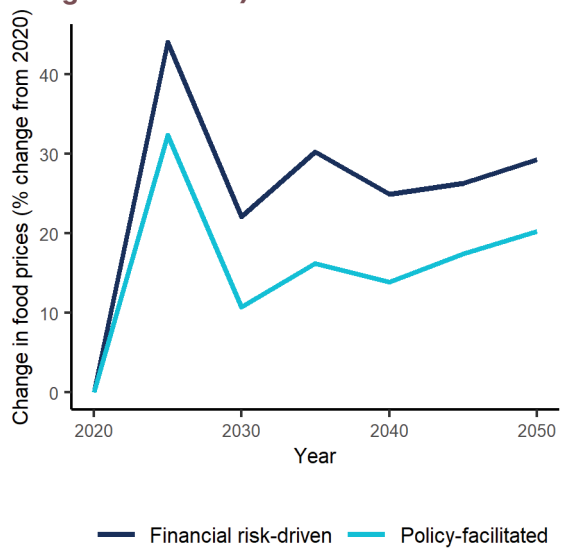
In the short run, both reactions lead to increased prices. The price increase is the strongest for the least sustainable sub-sectors, including beef production, dairy, and crops, such as soy or palm oil, which put a lot of pressure on land systems. The speculative activity in the commodity markets may additionally increase the volatility of prices (Box 1). This short-term food price increase results in reduced food affordability, forcing consumers to switch to cheaper products or reduce their consumption if there are no affordable alternatives. In the long run, the market gradually adjusts, productivity increases, and prices fall (Figure 15).

The gradual 'policy-facilitated' transition lowers AFOLU producers' costs and boosts land productivity, limiting the food price increase. In this scenario, there are a few factors that limit the price increase:

- Transparent communication on expected emissions and biodiversity price trajectories combined with sustainability investment incentives encourage producers to invest in the transition early and gradually and reduce the chances of a sudden financial sector response and limits its scale.
- Policies stimulating investment in yield-enhancing technologies increase productivity of agricultural land in the 'policy-facilitated' scenario by more than in the 'financial risk-driven' scenario. Higher productivity of land translates into lower land prices in the 'policy-facilitated' scenario, despite the land demand from nature restoration activities.

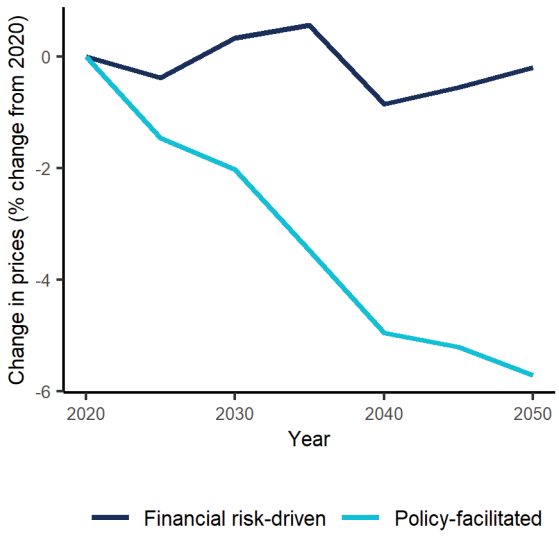
Overall, in the 'policy-facilitated' transition, the food prices grow more slowly than in the 'financial risk-driven' transition. In the long term, due to the investment in productivity-enhancing innovation, higher yields temper the price growth (Figure 15). By 2050, food prices are 9% higher in the 'financial risk-driven' scenario than in the 'policy-facilitated' scenario.

Figure 15. Global average food price (% change from 2020)



Source: Vivid Economics

Figure 16. Global food price in fruits, vegetables and nuts (% change from 2020)



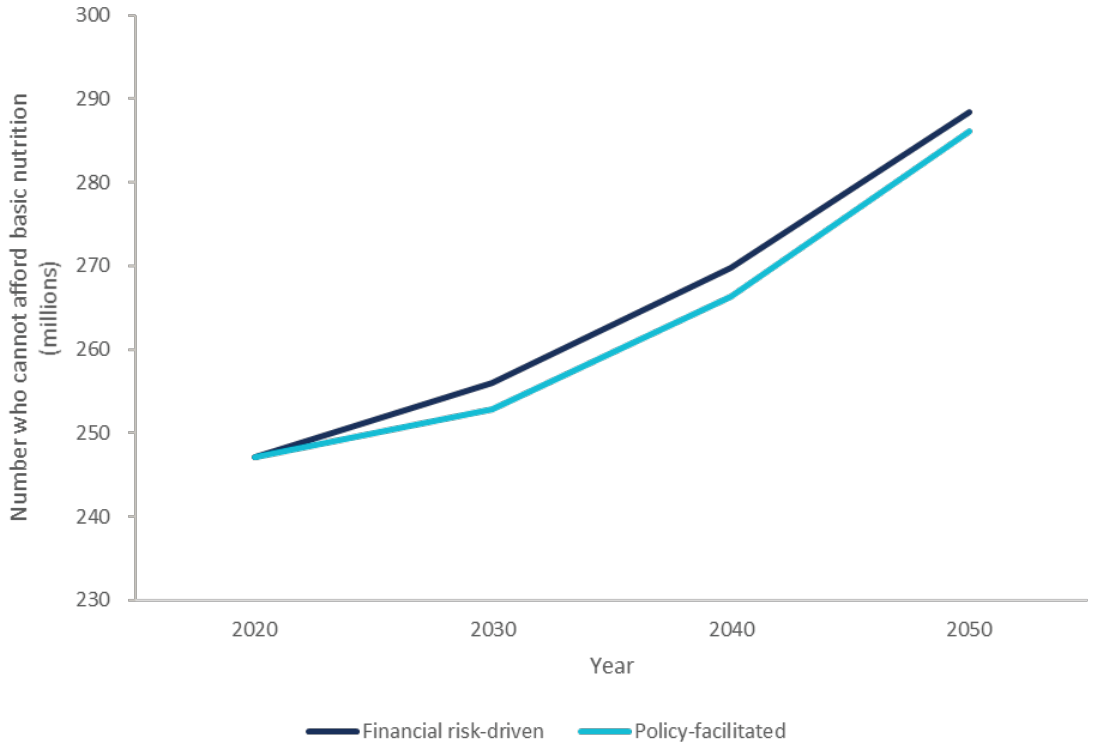
Source: Vivid Economics

The food price increase in the 'financial risk-driven' scenario imposes a burden on vulnerable consumers. Land and emissions-intensive products are most affected by the transition, meaning consumers may spend a higher share of their income on food or make changes to their diets; namely, by shifting away from products like beef and dairy. The price increase in the 'financial risk-driven' scenario also affects plant-based products (Figure 16). As a result, people further switch from more expensive and diverse sources of vitamins and minerals, such as a balanced mix of vegetables and fruit, to less costly and nutritious starchy food. In the most vulnerable communities, basic nutrition needs are not satisfied. Such changes in diet will have consequences on people's health.[85] In the long term, as the food system and the finance system adjust to the transition, the situation is likely to improve slowly.

Higher food affordability and development of alternative protein products improve the nutrition outcomes in the 'policy-facilitated' scenario. The difference between scenarios peaks in 2040 when in the 'policy-facilitated' scenario roughly 3.3 million **more** people can afford a sufficient diet compared to the "financial-risk driven". As food affordability in the 'policy-facilitated' scenario is higher than in the 'financial risk-driven' scenario, the impact on access to food is not as severe as in the 'financial risk-driven' scenario (Figure 17). Additionally, the scenario assumes public support for innovation in alternative protein products, resulting in affordable low-emissions alternatives to meat. This could further improve nutrition.[86] As a result, in the 'policy-facilitated' scenario, the poorest households

are more likely to afford a diet offering enough calories (Figure 17), proteins and other nutrients than in the 'financial risk-driven' scenario. Moreover, the forward-looking and proactive policymaking of the 'policy-facilitated' scenario offers a possibility to anticipate the decreased access to food and support vulnerable consumers through interventions such as cash transfers, community kitchens, and surplus food hubs (limiting food waste) and support for own-needs urban agriculture. In the 'financial risk-driven' scenario, this support would be more costly due to greater needs and higher food prices.

Figure 17. Nutrition cost (number of people who cannot access basic nutrition)



Source: Vivid Economics

4 Deep-dive on Brazil

A transition facilitated by policy intervention has better economic and social impacts in Brazil than a 'financial-risk driven' transition. Consistent with the global results, rapid capital reallocation in a 'financial risk-driven' transition imposes higher environmental, economic and social consequences for Brazil than a 'policy-facilitated' transition. This section explores the results for Brazil of the two global scenarios, following the framework of four normative outcomes set out in Section 3: climate (Section 4.1), nature (Section 4.2) income and jobs (Section 4.3), and affordable nutrition (Section 4.4).

4.1 CLIMATE CHANGE

The 'policy-facilitated' transition leads to lower GHG emissions than the 'financial risk-driven' transition in Brazil.

- Key drivers of the differences between the scenarios include policies stimulating investment in productivity-enhancing technologies and nature restoration.
- The impact of both scenarios on emissions in Brazil is relatively better than globally because of the country's focus on land and emission-intensive products.

Brazilian food system contributes significantly to global emissions.[87] In 2019, AFOLU emissions constituted roughly 60% of Brazil's total emissions.[88] [89] Brazil generates 12% of global AFOLU emissions, positioning it among the greatest polluters in the sector.[88] Nearly half of the emissions of Brazilian AFOLU come from deforestation for commodity agriculture, including pastureland.

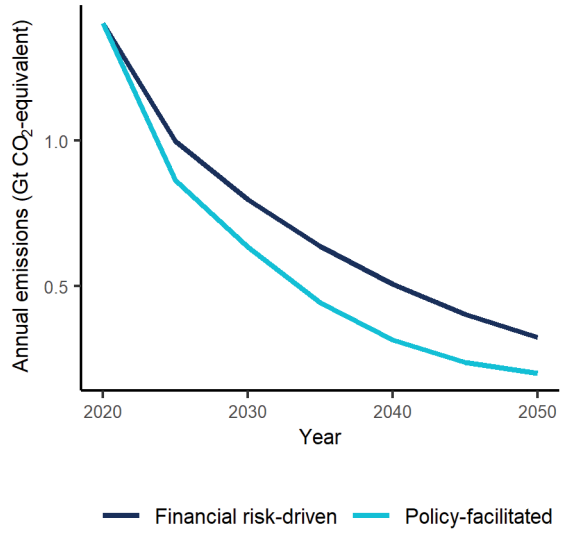
The 'policy-facilitated' transition leads to lower emissions than the 'financial risk-driven' transition. The decrease in emissions is more substantial in the 'policy-facilitated' scenario than in the 'financial risk-driven' scenario (Figure 18). By 2050, emissions in the 'policy-facilitated' decrease by 85%, compared to 77% in the 'financial risk-driven' scenario. In both scenarios, the total AFOLU emissions decrease mainly due to the CO_2 emissions reduction induced by the cost of GHG emissions. Additionally, in the 'policy-facilitated' scenario, an increase in forest cover further reduces CO_2 emissions (Figure 19). As a result, in the 'policy-facilitated' scenario, Brazilian AFOLU reaches net-zero emissions of CO_2 in the early 2030s, roughly a decade ahead of the 'financial risk-driven' scenario.

Key drivers of the differences between the scenarios include policies stimulating investment in productivity-enhancing technologies and nature restoration. AFOLU producers reduce their emissions in both scenarios to limit the cost of GHG emissions. However, there are two main aspects of the 'policy-facilitated' scenario differentiating it from the 'financial risk-driven' scenario that are responsible for the differences in outcomes between the scenarios:

- In the 'policy-facilitated' scenario, policies encourage investment in yield and sustainability enhancing technologies, while no such support exists in the 'financial risk-driven' scenario. Policies limiting the transition's cost or risk for producers and lenders, combined with emissions pricing are more effective than the increased cost of capital imposed by the financial sector in the 'financial risk-driven' scenario. For example, less land is needed to produce the same amount of output. Overall, the policies limit emissions of AFOLU in Brazil.
- The 'policy-facilitated' scenario also assumes policies stimulating nature restoration and carbon sequestration activities, while the 'financial risk-driven' transition does not incentivise such activities. These policies turn some of Brazil's cropland and pastureland into forests in the 'policy-facilitated' scenario (Figure 21), further reducing emissions.

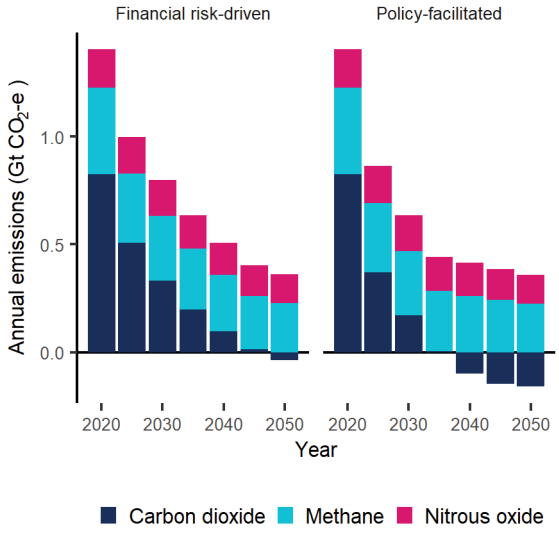
The impact of both scenarios on emissions in Brazil is relatively better than globally. The results for Brazil indicate higher relative emissions reduction than globally. This is because Brazilian agriculture focuses largely on several products with high emission and land intensity (beef, soy), disproportionately likely to be affected by capital reallocation away from unsustainable forms of production. Additionally, the conversion of mainly pastures and cropland into forests in the 'policy-facilitated' scenario takes place in Brazil on a larger scale than globally. This is explained again by the country's focus on products that are land and emissions-intensive compared to other agriculture products, but also by the potential for nature restoration. In the 'policy-facilitated' scenario, the Brazilian AFOLU sector offsets most of its own GHG emissions by 2050 (Figure 19). Globally, this is not the case (Figure 8).

Figure 18. Annual AFOLU emissions in Brazil



Source: Vivid Economics

Figure 19. Annual AFOLU emissions by GHG in Brazil



Source: Vivid Economics

4.2 NATURE

The 'policy-facilitated' transition restores Brazil's ecosystems more effectively than the transition driven by financial risk.

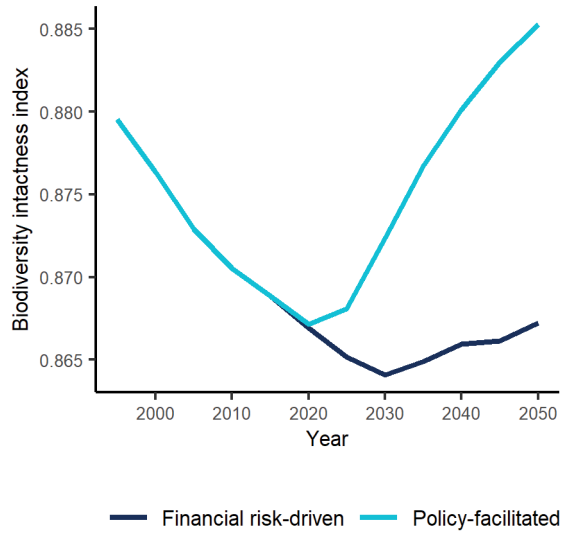
- The scenario assumes policies stimulating nature restoration, turning some of Brazil's cropland and pastureland into restored natural ecosystems.
- The effectiveness of these policies in Brazil is higher than globally, as Brazil's AFOLU is disproportionately focused on land-intensive products and has a high potential for nature restoration.

Despite efforts to protect Brazilian forests, the country's food system contributes significantly to nature degradation.[87] Roughly 10% of the world's forest cover is located in Brazil, hosting between 15-20% of the world's biological diversity, with the greatest number of endemic species on a global scale.[90] Deforestation linked to agricultural expansion is a longstanding problem in Brazil, eliciting political promises of improvement. In the early 2000s, Brazil made important efforts to protect its forests and biodiversity. [88] Unfortunately, the effect of these efforts was not long-lasting, and since 2016, deforestation rates in Brazil have been on the rise again.[91]

The 'policy-facilitated' transition supports Brazil's nature restoration efforts more effectively than the transition driven by the financial risk. The 'policy-facilitated' scenario starts to reverse the damage done to biodiversity, as measured by Biodiversity Intactness Index (BII), while the 'financial risk-driven' only stabilises the BII (Figure 20). Overall, the 'policy-facilitated' scenario leads to better environmental outcomes than the 'financial risk-driven' scenario. Specifically, the 'policy-facilitated' scenario restores 1995 levels of biodiversity by 2040; the 'financial risk-driven' scenario does not reach 1995 levels in the time frame under consideration.

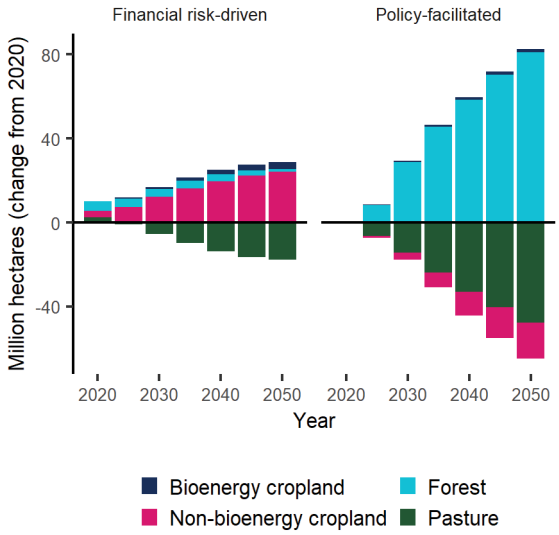
Policies stimulating investment in natural ecosystems restoration are the main driver of differences between the scenarios. AFOLU producers reduce their nature damage in both scenarios to avoid emissions and biodiversity costs. However, the 'policy-facilitated' scenario additionally assumes policies stimulating nature restoration, offering rewards for such activities. These policies contribute to turning some of Brazil's cropland and pastureland into restored natural ecosystems in the 'policy-facilitated' scenario (Figure 21). This supports the country's efforts to protect its valuable forests and biodiversity.

Figure 20. Biodiversity intactness index for Brazil



Source: Vivid Economics

Figure 21. Agricultural and forest land change in Brazil



Source: Vivid Economics

4.3 INCOME AND JOBS

The 'policy-facilitated' transition for Brazil results in GVA and direct employment almost doubling over 2020-2050, an outcome that is much better than in the 'financial risk-driven' scenario or either of the global scenarios.

- Brazil's competitive advantage in livestock production turns the transition into a positive one for economic activity and jobs in both scenarios.
- Additionally, nature restoration activities supported in the 'policy-facilitated' scenario, contribute to the GVA and employment growth in the extent not observed on the global scale.

The Brazilian AFOLU sector's tight links to the financial sector mean that the real economy is vulnerable to negative effects if the transition is not properly managed. Although in 2021, agricultural production accounted for only about 8% of Brazil's GDP, the value-added generated by the F&A sector as a whole (including supplies, industry, services, and agricultural production) was 3.5 times higher.[92] Agriculture accounts for 18.2 million or 20% of all existing jobs in Brazil[88] and more than 40% of Brazilian exports.[93] This important sector is linked to the financial sector through large food producers and the production of globally traded products, such as beef, soy, sugar cane and coffee. High exposure of the financial sector to agriculture makes it vulnerable to profit losses, deteriorating credit ratings and reduced access to finance in international markets. The potential negative impact of the abrupt transition on the food sector could exacerbate 'Brazil's long-standing challenges of low growth, high debt, and elevated levels of poverty and inequality' (IMF).[94]

Over the period 2020-2050, a 'policy-facilitated' transition supports almost a doubling of both economic activity and of direct employment in Brazil's AFOLU sector, mainly driven by the economic opportunities created by ecosystem restoration activities. For most AFOLU activities, employment and GVA are at a similar level in both scenarios. However, due to policies stimulating nature restoration and carbon offsetting, forestry activities generate much higher GVA and jobs in the 'policy-facilitated' scenario (Figure 22, Figure 24). Importantly, despite competing for land with other land uses, forestry grows without hampering food production. Although pasture areas decrease in the 'policy-facilitated' scenario (Figure 22), GVA and employment in this land class do not. This is due to the strong increase in productivity of agricultural land in the 'policy-facilitated' scenario. Technological improvement increases output per hectare of agricultural land while also increasing employment per unit of land. Overall, AFOLU employment in the 'policy-facilitated' scenario grows by 87% and GVA by 99% respectively between 2020 and 2050. The levels reached in 2050 are 59% higher than in the 'financial-risk driven' scenario for employment, and 73% higher for GVA.

Brazil's competitive advantage in both livestock and NBS production turn the transition into a positive for economic activity and jobs, as these indicators see double digit growth in both scenarios. Brazil is reliant on products that are emission and nature-intensive relative to other agriculture products, such as soy and beef. Therefore, theoretically, increased cost of carbon and biodiversity loss in both scenarios disproportionately affect Brazilian AFOLU producers' profitability and/or competitiveness. However, contrary to the global results, for Brazil, pastureland GVA and employment grow in both scenarios. This indicates that Brazil has a comparative advantage in meat production and despite increasing costs can maintain production by increasing prices. As beef is an important commodity for Brazilian AFOLU, the growing meat production GVA and employment significantly contribute to the total AFOLU GVA and employment. Brazil also has a comparative advantage in forestry, which is responsible for the relatively high effectiveness of the interventions in the 'policy-facilitated' scenario. As a result, the economic outcomes for the Brazilian AFOLU in both scenarios are much higher than globally. AFOLU employment in the 'policy-facilitated' scenario grows by 87% between 2020 and 2050, while in the financial risk-driven scenario it grows by 18% over the same period. Similarly, between 2020 and 2050, AFOLU GVA for Brazil grows 99% in the 'policy-facilitated' scenario and 15% in the 'financial risk-driven' respectively. The transition also has a downside, as both GVA and job levels for crop production decrease over 2020-2050, and those are the sectors in which family farmers are predominant.

Figure 22. GVA in AFOLU in Brazil by land class – Financial risk-driven

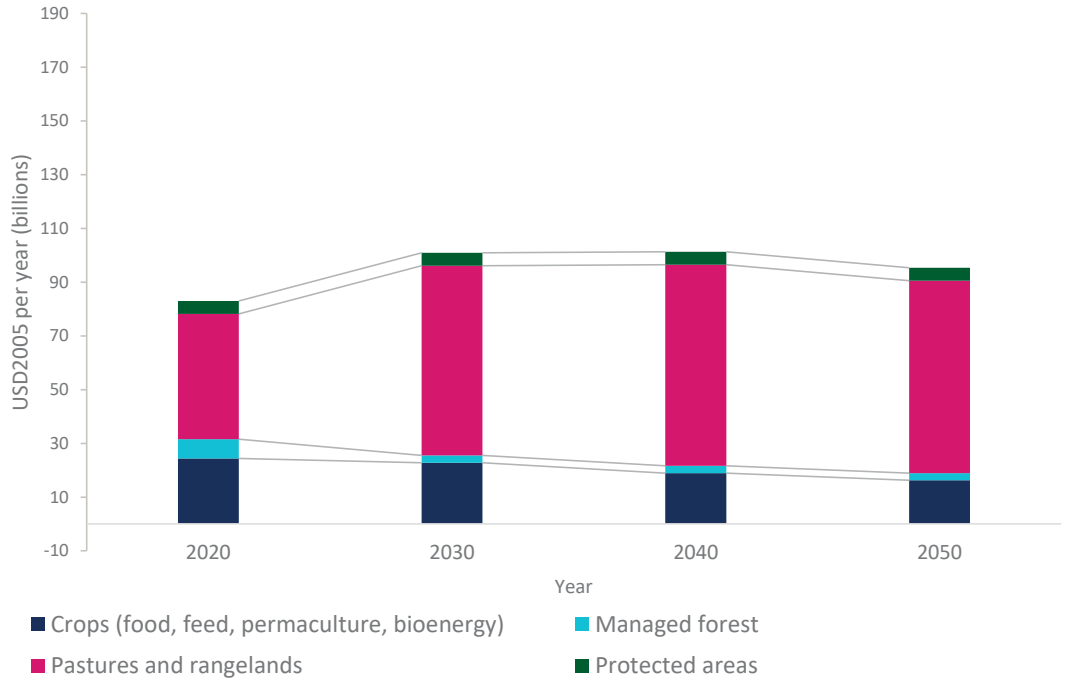
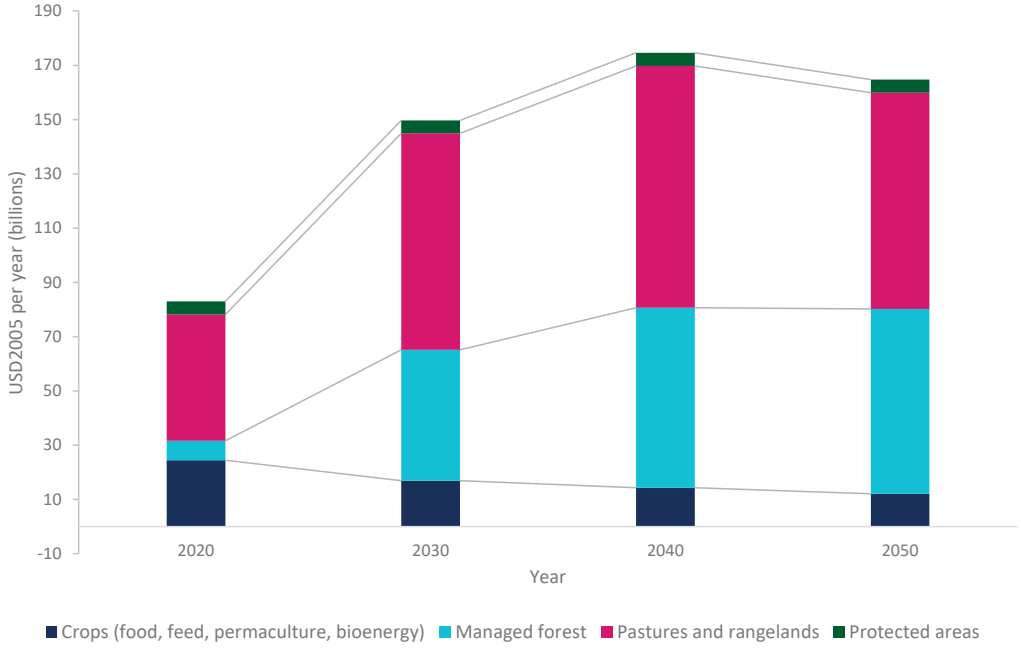


Figure 23. GVA in AFOLU in Brazil by land class – Policy-facilitated



Source: Vivid Economics

Figure 24. Employment in AFOLU in Brazil by land class – Financial risk-driven

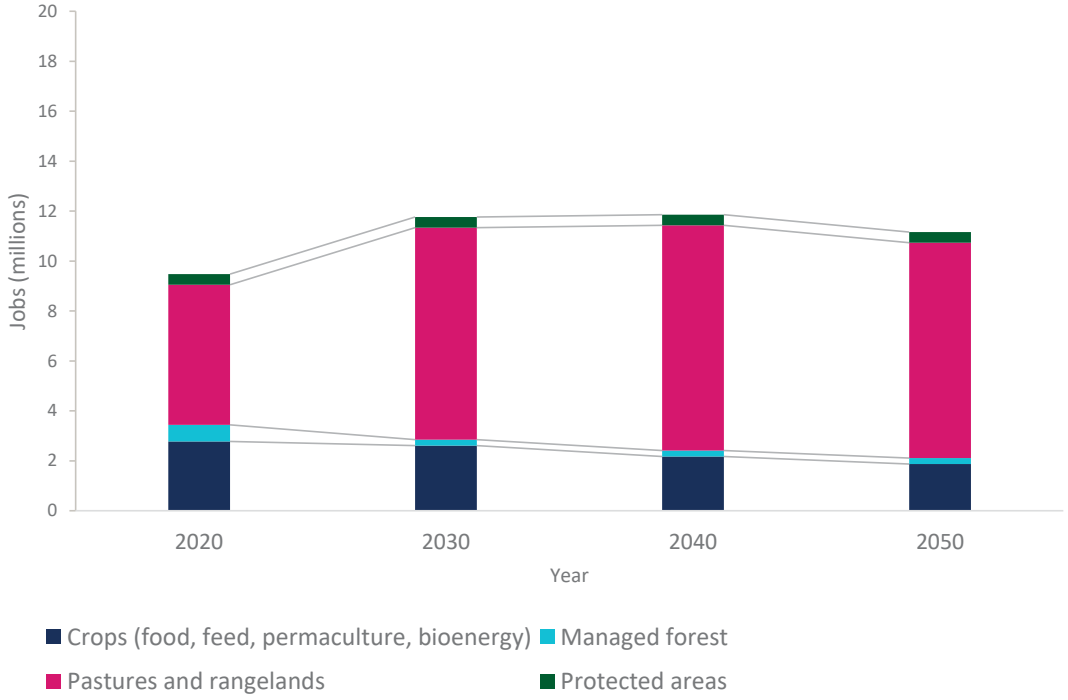
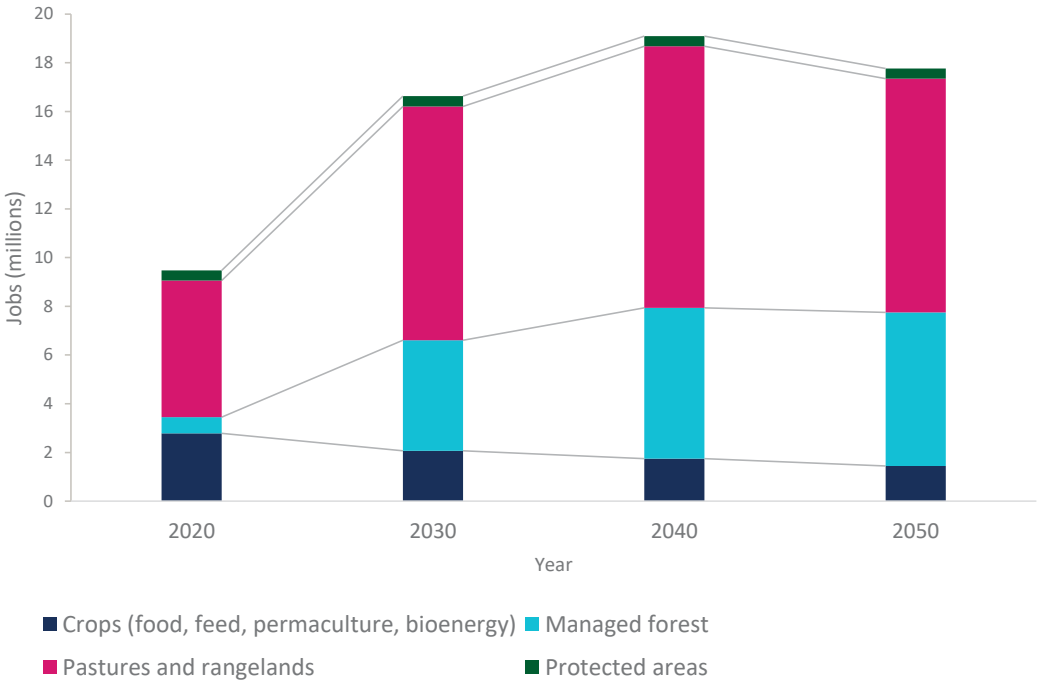


Figure 25. Employment in AFOLU in Brazil by land class – Policy-facilitated



Source: Vivid Economics

4.4 AFFORDABLE NUTRITION

In both scenarios, the transition reduces food affordability in Brazil more than globally, as intensive land competition in in the country drives food prices higher.

- The negative impact of the food price on food affordability will be less strong in the 'policy-facilitated' scenario, due to the nature restoration activities, offering employment opportunities.
- Moreover, policies that could mitigate the negative social impact of increasing food prices will be less costly and easier to implement in the 'policy-facilitated' scenario.

Brazil struggles with high levels of poverty and inequality, which compromise affordability of nutrition. Income inequality in Brazil as measured by the GINI index is the second-highest in South America and among the highest in the world.[95] In recent years, largely due to the 2015/16 recession[96] and the COVID-19 pandemic, poverty and inequality have increased.[97] With the increasing poverty, social inequalities and food prices, food affordability decreased.[98] According to the Brazilian Family Budget Survey, in 2018, 63% of Brazilians had access to sufficient amounts of safe and nutritious food for normal growth and development and active and healthy life.[98] The remaining population experienced food insecurity ranging from mild (compromising food quality to maintain the quantity consumed) to severe (reducing consumption, also among children), hunger. Food insecurity affects nutrition and health. In the last few decades, the dietary nutritional profile has additionally deteriorated due to the greater inclusion of processed foods in the diet.[99] Although the prevalence of symptoms associated with low-calorie intakes, such as being underweight, has decreased, obesity and diabetes in Brazil have increased.[100]

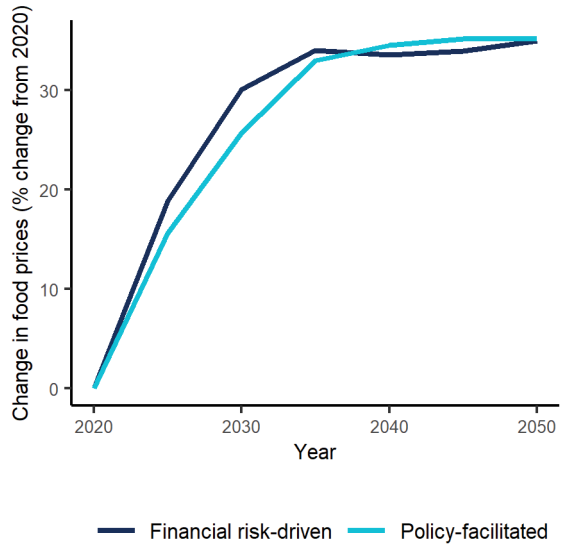
The transition may further compromise food affordability in Brazil as in both scenarios, high land competition drives food prices higher. In both scenarios, food prices increase by more than 30% between 2020 and 2050 (Figure 26). This reflects the degree of land competition between different land uses and the high emission intensity of the production. In both scenarios, deforestation, which was the major source of agricultural land, is halted due to the associated emissions. In the 'policy-facilitated' scenario, reforestation activities further increase land prices. Moreover, in both scenarios, prices of products having the highest environmental impact (beef) will increase due to externalities being included in the production costs. Overall, in both scenarios, food prices increase more than globally.

The negative impact of the food price on food affordability will be stronger in the 'financial risk-driven' scenario. In both scenarios, especially at the beginning of the transition, the food price increase is rapid. The average income increases slowly in both scenarios, and the distribution of this increase in an unequal country may be skewed towards the richer population. Therefore, sudden increases in food prices may impact food affordability and further disadvantage the poorest by affecting their already difficult financial situation, their nutrition and, as a result, their health (Figure 27). Importantly, in the 'policy-facilitated' scenario this effect will be less severe, as the forestry sector offers new

employment opportunities. Additionally, appropriate policies could mitigate the negative social impact of increasing food prices.

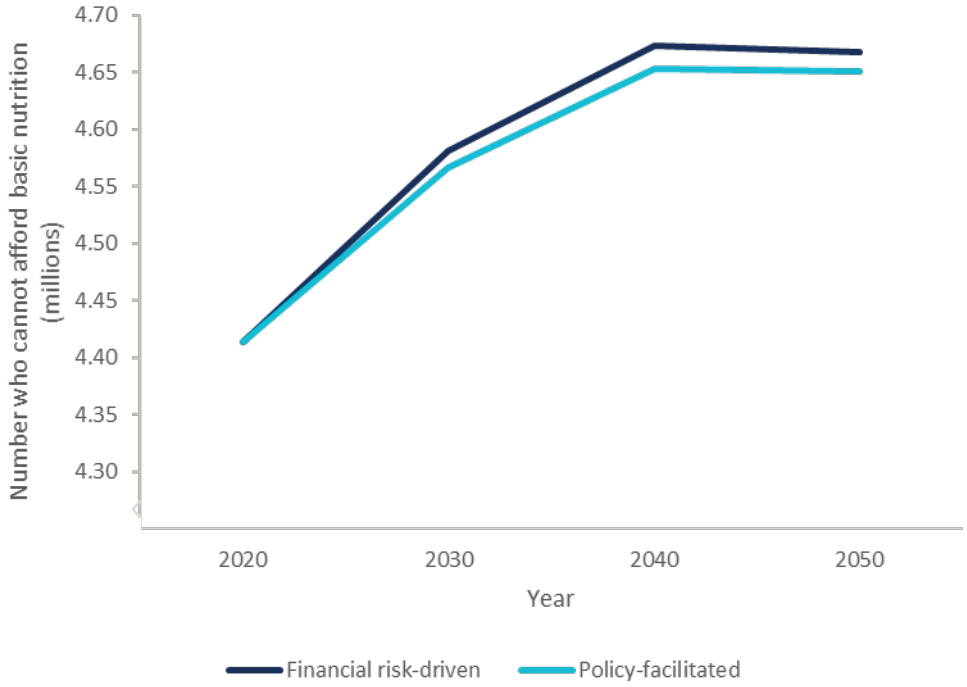
Regardless of the type of policies supporting access to food in Brazil, they will be less costly and easier to implement in the 'policy-facilitated' scenario. Nature restoration activities create jobs and generate public sector revenues. Therefore, an efficient intervention supporting food affordability will be easier in the 'policy-facilitated' scenario. There are multiple forms of potential support that already proved to be successful in Brazil. First, cash transfers are generally a well-researched and relatively efficient way of supporting food-insecure vulnerable populations.[101] Brazil's experience with cash transfer programs dates back to the 1990s. For example, Bolsa Familia established in 2003 to support low-income households has contributed to reducing inequalities in the country.[102] Additionally, policymakers could support different forms of infrastructure for food security with the financial and organizational support of the public sector. In Brazil, traditional examples of such infrastructure would be community kitchens and popular restaurants, which since the 1950s have provided affordable meals to workers and their families, and in 2003 became a part of the government's Zero Hunger strategy.[103] Located in poorer, mainly urban areas, they distribute food and meals free of charge or at subsidized affordable prices. Since the early 2000s, Brazil also has had food banks redistributing food donated by supermarkets, restaurants, the food industry and farmers and aiming at reducing food waste. Finally, support for peri-urban and urban agriculture, including municipal farms and gardens, helps promote food security and creates jobs.[104,105] As, in line with the global trends, the urban population in Brazil has doubled since the mid-1980s and keeps growing, such initiatives could complement other policies well.[106]

Figure 26. Food price index in Brazil (2010 = 100)



Source: Vivid Economics

Figure 27. Nutrition cost (number of people who cannot access basic nutrition) in Brazil



Source: Vivid Economics

5 Implications for the financial sector

Our results indicate that an abrupt correction for climate and nature risks by a financial sector that is 'playing defence' leads to outcomes that are likely to be worse for the financial sector itself. The 'financial risk-driven' scenario assumes that external events trigger the financial sector to suddenly price in accumulated climate and nature risks. The response is abrupt because once a risk becomes salient, financiers tend to fully integrate it in decision making, thereby bringing forward future expected events. Prior to such an adjustment the sector is seen as building continued exposure to these risks, as there is no direct downside to it and individual financiers might anticipate that they can limit their losses by being the first to divest from the riskiest activities. However, this reactive mode could ultimately create a less attractive trajectory for the sector as a whole. Our scenario shows that a correction by the whole sector in 2025 can still reduce the impact on climate and nature, but it does so at the cost of income (GVA) and jobs. And the outcomes can become even worse if the abrupt response is delayed, with climate and nature risks accumulating further.

A gradual 'policy-facilitated' transition offers better outcomes for the real economy and, consequently, also for the financial sector. Our modelling results suggest that a transition leading to the same emissions and nature loss valuation in 2050 leads to better economic and social outcomes in relation to the AFOLU sector when facilitated by gradually introduced policies than when driven by an abrupt response in the financial sector. The higher economic activity and direct employment in the AFOLU sector in a 'policy-facilitated' transition are likely to benefit the financial sector, as they are positive for borrowers' ability to pay back loans and to make more productive investments.

Both policy makers and financiers can take actions that help move away from a disruptive, risk-driven transition to one that is smoother and more orderly. The two contrasting scenarios analysed here suggest that financiers and policymakers at all levels (local, national and international) can take steps to advance a more orderly and successful transition for the food and agricultural system. While a pathway reliant on financial risk pricing can improve environmental outcomes, the dynamics examined here point to a way forward that could facilitate better environmental, economic and social outcomes.

Even in the absence of appropriate policy, the financial sector can pro-actively act to reduce the negative impact of its financing and risk-pricing on GHG emissions and nature loss. The financial sector is not only affected by climate and nature risks, but it is also driving them through the activities it finances. Hence, the sector can be an active agent that advances the gradual transition. Prompt action is required because such a gradual implementation is only possible in the short term. Delays will only cause climate and nature-related risks to accumulate and increase the costs, as also revealed by the results of the ECB climate stress-test.[6]

The financial sector has several levers it can pull to advance a gradual transition:

i. **improving the quality of risk assessments and encouraging disclosure by corporates.** An important first step the financial can take is to support and invest in advancing the assessments of climate and nature-related risks to a level that can be included in decision making. The main reason for these risks not to be included in current decision making in the financial sector is the fact that the outcomes are still very uncertain, so they cannot be quantified sufficiently to feed into regular risk and strategy models. The development of climate and nature-related data has seen significant progress in recent years and the regulatory push for disclosure is increasing. The sector can build on this momentum by engaging with corporate clients to collect necessary data and to encourage disclosure and by investing in the development of the necessary insights for the data.

ii. **taking action that do not affect capital requirements such as raising awareness about climate and nature risks with borrowers**. There are many actions the financial sector can take to advance a gradual transition that do not affect their capital requirements. For example, lenders can engage with clients to raise awareness about climate and nature risks and advise them on how to best fare the transition. Being at the centre of economic activity financial institutions are in a unique position to develop insights on this, insights that can enable companies to incorporate climate change and nature valuation into their decision making.

iii. **gradually integrating these risks into risk management and strategy to avoid the accumulation of risk and sudden repricing**. Eventually, the financial sector needs to translate the risk assessments into risk management and commercial strategy. Improved quantification of climate and nature-related risks will inform decision making. A gradual approach enables a gradual transition**.** In the current situation in which outcomes remain highly uncertain, the financial sector can start by integrating current urgencies such as deforestation into risk management and business strategy.

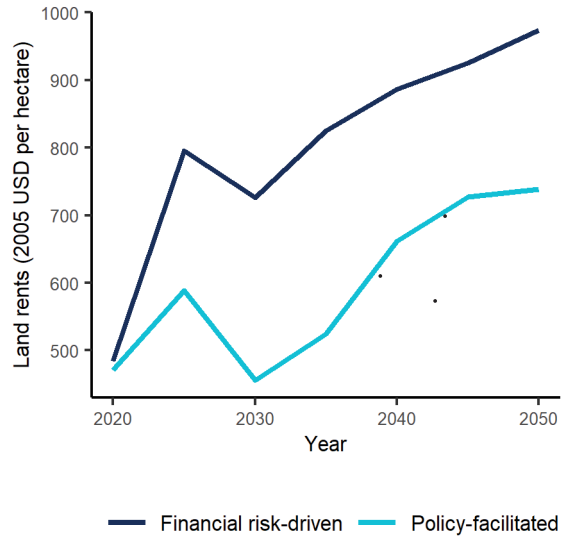
iv. **deploying more capital to proven NBS and improved agricultural practices that serve as a hedge in the transition.** The financial sector can also steer any funding dedicated for innovation towards the financing of sustainable agriculture and innovations. It can also pro-actively identify proven technologies that can reduce climate and nature-related risks (e.g. proven NBS technologies). Such deployment of capital also does not affect capital requirements and serves as a hedge in the transition.

Nevertheless, only policymakers can create an enabling environment for transition-related financing, including market structures that support sustainable revenue models and appropriate support to de-risk investments with positive systemic spillovers. While the financial sector can price in climate change and nature-related risks, only policymakers can create an enabling environment and de-risk investments in sustainable innovation and unproven technologies. The types of policy options include (i) pricing of GHG emissions and nature exploitation (whether through tax or trading systems); (ii) direct support measures for development of NBS or improved agricultural technologies and practices,

including for large and small enterprises; (iii) public financing mechanisms to de-risk private finance into emerging sectors and technologies, or with harder-to-finance counterparties; and (iv) social support policies to help mitigate the negative health and nutrition impacts on the most vulnerable populations. The financial sector can engage with policymakers to support processes related to these interventions. We also note that effective policymaking requires the support of various stakeholders such the private sector and civil society.

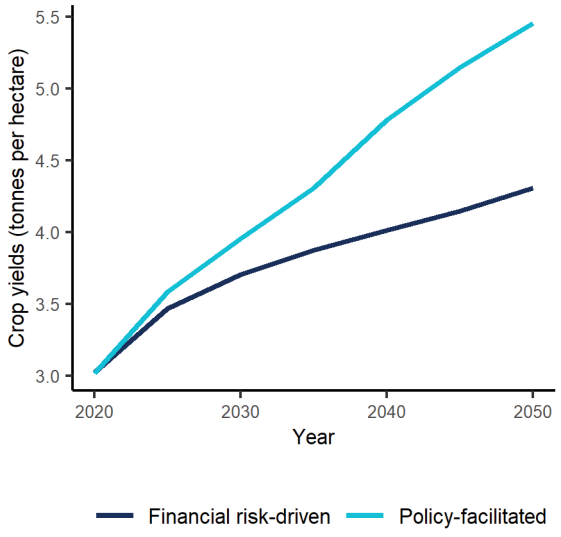
Annex 1. Supplementary figures

Figure 28. Global land prices



Source: Vivid Economics

Figure 29. Global crop productivity (tonnes of dry matter/ha)



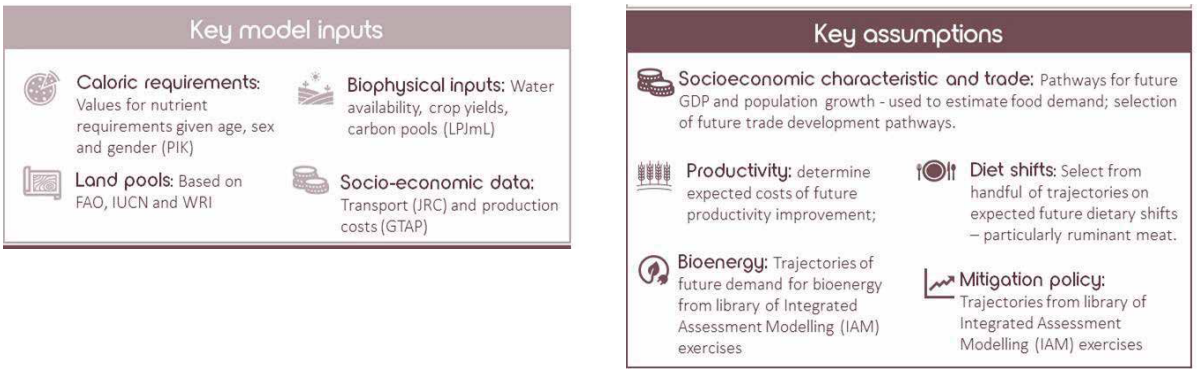
Source: Vivid Economics

Annex 2. Modelling approach

The Model of Agricultural Production and its Impact on the Environment (MAgPIE[63]) is a partial equilibrium model of the global land use system which has been widely used by international bodies (such as the IPCC) to explore pressures on the land use system. The model takes population and GDP projections, caloric requirements, and demand elasticities as inputs to determine the least cost way to meet global food demand, while accounting for spatially disaggregated biophysical constraints including those on land and water, as well as potential crop yields (Figure 6).

MAgPIE is particularly useful for capturing land use dynamics and trade-offs. The model allows landowners in the model to invest in technological change and irrigation, and in so doing captures the effect of potential future increases in agricultural productivity. Figure 6. Model inputs and assumptions

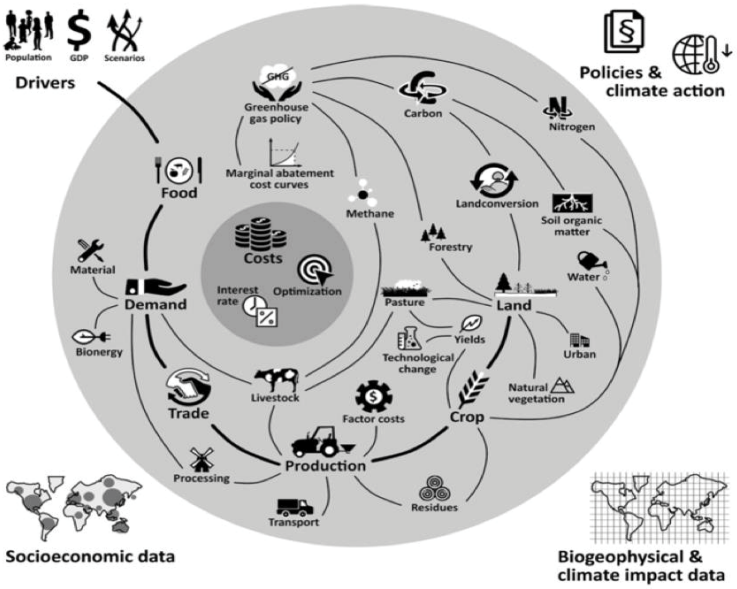
Figure 30. Model inputs and assumptions



Source: Vivid Economics

This framework allows land use competition between varying uses, such as forestry, bioenergy, and agriculture to be modelled explicitly. The model divides the world into 0.5-degree grid squares, with each grid square optimising land use and input consumption. This allows for mapping of both opportunities and land use change at more detailed scale. For this study we use MAgPIE 4.4[107] using the assumptions described in annex 3.

Figure 31. Model dynamics and trade-offs



Source: MAgPIE 4 – a modular open-source framework for modelling global land systems[107]

Annex 3. Scenario assumptions

Table 1 summarises the main scenario drivers and how they are represented in the model.

Table 1. Scenario narratives and modelling approach

	'Financial risk-driven' scenario	'Policy-facilitated' scenario
Transition-driving interventions (modelled in MAgPIE)		
Emissions pricing	Financial system prices in risk quickly and abruptly by bringing future risks/prices forward, meaning a large upfront spike in price expectations. After the initial adjustment, prices change gradually given the effort which is needed to reach net zero by 2050.	Policymakers coordinate to enact globally consistent emissions pricing policy and provide financial markets with information upfront regarding transition paths in a coordinated and proactive manner. The expected price therefore rises steadily in line with public communications.
Modelling approach (MAgPIE)	Adjusted NGFS Delayed Action scenario: CO_2e price rising sharply and then levelling off to \$600/tCO_2e by 2050	NGFS Net Zero 2050 scenario: CO_2e price rising steadily to \$600/tCO2e by 2050
Biodiversity pricing	Financial system prices in nature risk quickly and abruptly by bringing future prices forward, meaning a large upfront spike in price expectations. After the initial adjustment, prices change gradually given the effort that is needed to reverse nature losses by 2050.	Policymakers provide financial markets with information upfront regarding expected biodiversity price trajectories in a coordinated and proactive manner –price rises steadily in line with public communications.
Modelling approach (MAgPIE)	Adjusted NatuRisk 'Climate Nature Now' scenario: Biodiversity price rising abruptly to \$1000 per hectare by 2050.	NatuRisk 'Climate Nature Now' scenario: Biodiversity price rising steadily to \$1000 per hectare by 2050.

	'Financial risk-driven' scenario	'Policy-facilitated' scenario
Rate of investment in carbon-sequestering nature-based solutions (afforestation, land restoration, BECCS)	Policymakers do not create well-functioning offset markets to allow landowners to access the green upside nor do they provide rewards for negative emissions. Investment in afforestation and similar sequestration practices rises slightly, mostly due to social impact investing, but does not become mainstream.	Policymakers establish clear and straightforward rules around offset markets and rewards for negative emissions. This supports higher levels of investment in carbon-sequestering nature-based solutions.
Modelling approach (MAgPIE)	No carbon price-driven afforestation	Sequestration from afforestation rewarded at the price of carbon.
Rate of investment in nature-based solutions: water quality, soil quality, pollination (excluding carbon)	Policymakers do not create well-functioning biodiversity offset markets or other incentives for nature-based solutions. Non-sequestering nature-based solutions remain small-scale and mostly supported through concessionary or social impact investing.	Policymakers articulate a clear and straightforward rules around biodiversity offsets and rewarding gains in nature. This supports higher levels of investment in non-carbon-sequestering nature-based solutions.
Modelling approach (MAgPIE)	N/A (no carbon price-driven afforestation)	BII coefficient for carbon price-driven afforestation set to secondary vegetation (higher than timber plantations), thus providing an incentive for high-quality woodlands rather than planting of monocultures.
Cost of developing and adopting yield-enhancing technologies (innovation and catch-up)	Policymakers do not de-risk investment in yield-enhancing technologies (for example by providing research and development grants and incentives, protecting intellectual property and funding training programmes). Cost of technological development remains high and rate of technological improvement remains low.	Policymakers de-risk yield-enhancing technologies through research and development grants and incentives, protecting intellectual property and funding training programmes.
Modelling approach (MAgPIE)	Low rate of technological change	High rate of technological change
Cost of developing and adopting sustainable agriculture (innovation and catch-up)	Policymakers do not de-risk switching to sustainable agricultural practices like conservation-till farming, regenerative agriculture, cover cropping, integrated pest management, agroforestry/silvopasture, improved rice paddy management and development of alternative proteins.	Policymakers support development and adoption of sustainable farm practices through blended finance schemes, agricultural extension services and agricultural subsidy reform.
Modelling approach (MAgPIE)	Sustainable land management practices are undertaken endogenously in the modelling framework using marginal abatement cost curves (MACCs). However, MACCs do not represent interventions for which the science is less well-understood and those which are non-conventional or transformative (such as alternative proteins). Therefore, investments in and shifts toward alternative proteins are modelled explicitly using input of new diet trajectories. These are borrowed from an existing study and were selected to align with these scenario narratives. The 'financial risk-driven' scenario uses the '4° BAU' demand pathway.	The 'policy-facilitated' scenario uses the '1.5°C policy-driven' demand pathway.

Source: Vivid Economics

Other modelling assumptions are common to both scenarios:

- For the socioeconomic assumptions the IPCC SPSS 2 scenario is used.
- The remainder of settings use the MAgPIE default. This includes the impact of a changing climate on yields in the AFOLU sector.

Vivid Economics' inhouse input output model is used to estimate GVA and jobs. MAgPIE scenario outcomes are fed into the model for this purpose.

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Finance, Nature and Food Transitions

The impact of potential financial climate and nature risk repricing on normative outcomes for food systems

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NATURE FINANCE