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Developing climate transition scenarios to manage financial risks

The Banque de France and the ACPR have developed an analytical framework to quantify climate transition scenarios and assess the associated financial risks. This type of framework can be used to carry out climate stress test exercises. Its first application for France gives an order of magnitude for the possible adversity of the scenarios published by the Central Banks and Supervisors Network for Greening the Financial System (NGFS). It reveals that, while these scenarios may lead to only moderate macroeconomic impacts by 2050, they will entail major structural transformations, which are a source of financial risks for those financial institutions that are particularly exposed to the most impacted sectors and firms. Under disorderly transition scenarios, certain firms would be significantly more likely to default and the credit risk of the exposed financial institutions would increase.

Thomas Allen and Jean Boissinot
Financial Stability Directorate
Laurent Clerc
SGACPR – Research and Risk Analysis Directorate
Stéphane Dees
Macroeconomic Analysis and Forecasting Directorate

JEL codes
C60, E44,
E50, G32,
Q40, Q54

The effects in 2050 of a disorderly, sudden and severe climate transition (compared to a baseline orderly transition scenario):

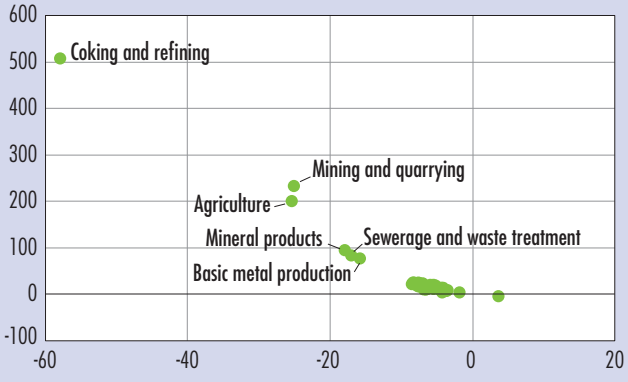
5.5% loss of GDP

58% loss of value added in the most affected sector, the coking and refining sector

6-fold increase in the probabilities of default in the coking and refining sector, rendering more than 50% of the sector's assets ineligible as collateral for monetary policy operations

Impacts of a sudden transition on value added and probabilities of default in the most affected sectors in 2050

(% deviation from the baseline orderly transition scenario; x-axis: value added; y-axis: probabilities of default)



Source: Allen et al., 2020.

1 The transmission of climate shocks

Climate change presents an unprecedented challenge to economies and, by extension, to the financial system. The risks associated with climate change are generally broken down into two types: physical risks, associated with the direct impacts of climate change (increased frequency and severity of extreme weather events); and transition risks, related to more or less orderly transitions towards a low-carbon economy and its associated economic structural changes. Each of these two "families" of risks has their own different channels of transmission to the economy and hence to the financial system.

The increase in the frequency and severity of extreme weather events will trigger, for example, the destruction of infrastructure or real estate assets and disruption to the operations of firms and financial players, necessitating spending on reconstruction or adaptation. For households, these events could, for instance, lead to losses of income due to adverse effects on labour productivity, or of wealth, through damage to property. At the macroeconomic level, they would lead to an increase in the capital depreciation rate, a greater need for investment, disruptions to international trade, and a reduction in tax revenues due to the decline in economic activity. Without additional transition measures, the NGFS[1] estimates that total cumulative GDP losses from physical risks will amount to 13% globally in 2100,[2] but with major variations from region to region (NGFS, 2021).

Transition risks arise from the potential repercussions of the transition towards a low-carbon economy, which could lead to economic shocks with financial implications, particularly if the transition is implemented in a disorderly manner, i.e. inadequately anticipated, poorly coordinated or simply too late. These shocks can be very different in nature. Climate policies, such as introducing a carbon tax, banning combustion engine vehicles or imposing energy efficiency improvements, are intended to promote "decarbonised" solutions and to penalise activities that emit greenhouse gases (GHG). As such, they impact the profitability of these activities and could, for example, lead to expected returns being dramatically reassessed in certain – particularly carbon-intensive – sectors in the event of sudden changes in expectations. The market value of assets referred to as stranded assets could suffer a severe correction. Disruptive technological innovations would have similar effects, rendering previous production processes and their investments obsolete. Changes in consumer and investor preferences and behaviours could also lead to the reassessment of growth outlooks and asset values in certain sectors. According to the NGFS, transition risks will have a far lesser economic impact than physical risks, with a loss of GDP of almost 2.5% in 2100 in the event of a delayed transition (NGFS, 2021). Conversely, transitioning towards a net-zero economy (Banque de France, 2021) in an efficient and orderly manner could even yield medium-term benefits thanks, among other things, to major investments in the construction and renewable energy sectors. However, the benefits of an orderly transition will primarily become evident in the longer term, particularly due to the phenomenon of climate inertia, which means that atmospheric warming and the damage it causes cannot be stopped immediately.

The downward reassessment of certain assets will affect the balance sheets of financial players, both banks and insurance companies, and the valuation of investment funds. These impairments could also decrease the value of collateral attached to loans. With regard to credit risk, default rates for the most exposed

1 The Central Banks and Supervisors Network for Greening the Financial System (NGFS) is an international network launched in December 2017 of 95 central banks and supervisors (as at June 2021) eager to share their best practices in the monitoring of climate-related financial risks and committed to working towards a more sustainable financial system.

2 This estimate only takes chronic impacts into account.

sectors and firms could also escalate and undermine the solvency of financial institutions. Following its pilot climate exercise, **the *Autorité de contrôle prudentiel et de résolution* (ACPR – Prudential Supervision and Resolution Authority) estimates a potential threefold increase in the cost of risk for French banks in the most climate-risk exposed sectors (mining and quarrying, coking and refining,[3] agriculture, etc.)** (ACPR, 2021). A rapid shift in investor behaviour could also lead to a materialisation of liquidity risk for certain investment funds and the valuation shocks could impact the revenues and wealth of investors. According to the results of a stress test exercise carried out within the framework of the Eurosystem (ECB/ESRB, 2021), upon the announcement of a disorderly transition, funds exposed to the sectors responsible for the highest GHG emissions could instantly shed almost 2% of their value on average, with the worst affected 25% losing more than 4% of their value.

Climate risks also have a direct impact on insurers' liabilities due to the risk of both the cost and frequency of claims increasing, leading to potential underwriting losses. **In its pilot exercise, the ACPR estimates that the cost of claims could rise by a factor of five to six in certain French departments between 2020 and 2050** (ACPR, 2021; see the results of the pilot exercise for further details). In the medium term, insurance companies could review their coverage and pricing of risks, thus worsening the protection gap in certain regions.[4] Lastly, climate risks could trigger a confidence shock, prompting investors to abruptly reallocate their portfolios and thus creating a "climate Minsky moment" through a mass sell-off of assets.[5]

2 Understanding the specificities of climate scenarios

As with "standard" stress test scenarios, climate scenarios are not forecasts. They present extreme but plausible future outcomes that highlight certain significant aspects of the issues and challenges associated with climate change. The impacts selected should reflect the orders of magnitude involved, but the scenarios are not a prejudgement of what is likely to happen or of what is desirable. On the contrary, these scenarios are voluntarily designed to be adverse.

Beyond the similarities, climate scenarios also and most importantly display a number of specificities that differentiate them from the type of standard stress test scenarios used by supervisors to assess financial institutions' capacity to absorb losses in the face of adverse economic and financial shocks (see table).

The specificities of climate scenarios

	Standard scenarios	Climate scenarios	
		Transition risks	Physical risks
Time horizon	Short/medium-term	Short, medium and **long-term**	Short, medium and **long-term**
Types of variables	Economic and financial	**Climate policies, technological innovations, behaviours**	Climate policies, technological innovations, environmental changes
Shock calibration	Based on historical data	Little to no guidance from history	Little to no guidance from history
Aggregation	National	**Sectoral**	Sectoral and **geographical**
Feedback loops	Macroeconomic models with financial frictions	Work in progress (e.g. interactions between public policy and the economy)	**Climate-Economy** interaction
Discount rate	Not used	Important for long-term analyses	Important for long-term analyses

Source: Banque de France.

3 Coking and refining refers to "Manufacture of coke and refined petroleum products" (NACE C19).

4 The insurance protection gap is the difference between policyholders' total losses and the losses covered by the insurers.

5 A climate Minsky moment is a climate analogy for the "moment" – hypothesised by Hyman Minsky – when investors turn and bulk-sell their assets, thus triggering a downward price spiral after a phase of intense speculative investment.

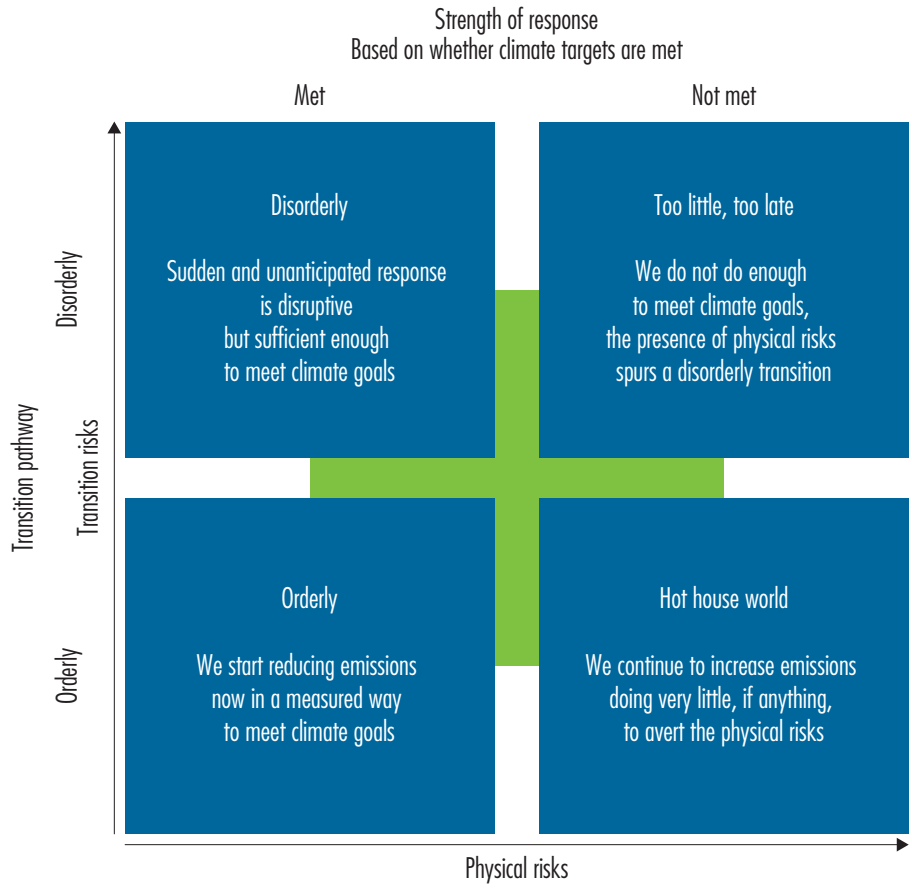
BOX 1

Climate scenarios of the Central Banks and Supervisors Network for Greening the Financial System (NGFS)

In June 2020, the NGFS published several reference scenarios featuring three different situations (see diagram). These scenarios were updated in June 2021.[1] The first family of scenarios refers to an "orderly" transition. Under these scenarios, the transition would have begun in 2020 with the proactive introduction of mitigation policies such as a carbon tax or support measures for renewable energies. It further assumes behavioural changes in consumers and financial players better aligned with the requirements of a low-carbon economy. This structural transformation of the economy, announced and anticipated, would take place gradually, without any major macroeconomic shocks. Meeting climate commitments would also help to reduce physical risks.

The second family of scenarios sets out the response to a "disorderly" transition, which could, for example, be delayed or sudden, but in both cases inadequately anticipated and therefore severe. In the event of a delayed

Categories of NGFS scenarios



Source: NGFS, 2020.

1 The June 2021 update reduced the dataset to six reference scenarios. The work undertaken by the Banque de France and the ACPR is based on the NGFS scenarios published in June 2020.

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transition, new, more stringent measures, for example, may be implemented, leading to more disruptive adaptations depending on the sector. Households and firms would thus have to rapidly change their behaviour, resulting in significant macroeconomic and sectoral upheavals. However, achieving climate goals mitigates the physical risks.

Lastly, the third family of scenarios, referred to as "hot house world", reflects "business as usual", with no additional transition measures from governments other than those already in place and no behavioural changes from economic players. Greenhouse gas (GHG) emissions continue to follow past trends driving a rise in temperature of more than 2°C, the aggravation of chronic physical risks and an increase in the frequency and severity of extreme weather events. Transition risks, on the other hand, remain limited.

New risk factors, neither financial nor economic in nature, must first be taken into account. In line with the transmission channels outlined above, shocks can be linked to extreme weather events, chronic physical impacts, the introduction of public policy measures, technological transformations, or changes in investor behaviours.

Unlike standard stress tests, climate scenarios rely on forward-looking data. Standard exercise scenarios are typically calibrated to past events, such as financial or real-estate crises or periods of recession or economic turmoil. In the case of climate scenarios, on the other hand, there is no historical precedent on which to build quantitative scenarios: climate change should lead to the structural transformation of our economies meaning that historical observations are of little use. The calibration of climate scenarios thus needs to be thought out differently, drawing on different sources of expertise such as the work of the Intergovernmental Panel on Climate Change (IPCC) on climate scenarios and long-term socio-economic pathways.

Climate change also imposes **far longer time horizons** than the three to five years generally used when performing standard stress test exercises. Physical risks could materialise in the long or shorter term and more or less severely depending on the geographical location. The transition could happen sooner, particularly in response to changes in the expectations and preferences of economic players and markets or in the wake of the introduction of climate-related policies. Climate scenarios must therefore incorporate short, medium and very long-term effects and also the ways in which they interact. Therefore, the sooner we implement the transition towards a low-carbon economy, the lower the likelihood of physical risk-related losses. However, it is important to note that due to a phenomenon of climate inertia, even if all commitments and recommendations are respected, temperatures should still rise by 1.5 °C by the end of the century and some physical risks will still materialise as a result of historical emissions.

Lastly, in order **to perform an economic assessment of the transition**, the – potentially disruptive – sectoral impacts of the structural transformations needed to achieve climate goals must be taken into account. Standard scenarios are based on the main macrofinancial aggregates, while climate scenarios have to specify the sectoral, and even infra-sectoral, effects associated with each of the proposed climate pathways. Within the most vulnerable sectors (due to their high emission levels or dependence on fossil fuels), certain players may be at a more advanced stage than others and able to benefit earlier from the opportunities provided by the transition. These heterogeneities between players must therefore be incorporated into climate scenarios in order to capture the magnitude of the most disruptive shocks to which financial institutions may be exposed.

3 Modelling the main transmission channels to capture the information needed

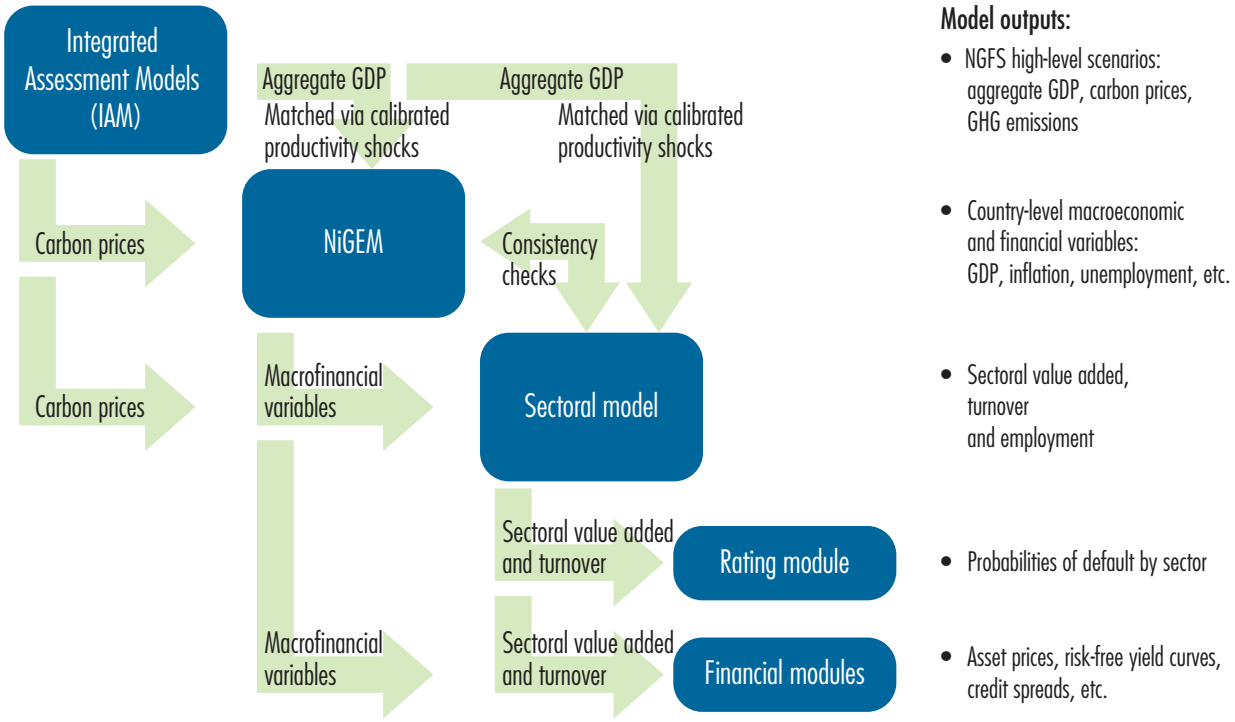
The NGFS has developed a number of climate scenarios in order to provide central banks and supervisors with a common framework at the international level for the monitoring of financial risks. Based on integrated assessment models,[6] these scenarios explore the different potential pathways for the transition towards a low-carbon economy and their associated physical impacts (see Box 1 above for further details).

This set of reference scenarios will help to ensure a degree of consistency and comparability across the climate stress test exercises carried out by the various authorities, but each jurisdiction still has a certain number of choices to make in their practical application. These choices apply to the number of scenarios, the time horizon, the type of risk, and the sectoral and geographical granularity of the analysis.

The ACPR thus **translated the NGFS scenarios into economic and financial impacts** in order to assess the vulnerabilities of its financial system (ACPR, 2020). As part of its pilot exercise, the economists at the Banque de France and the ACPR therefore developed a **new analytical framework** (see diagram) **based on a modular approach** (Allen et al., 2020).

The aggregated NGFS scenarios published in June 2020 provided the starting point for the model's development,[7] presenting trends in GDP, carbon prices and GHG emissions over the long-term at a highly aggregated level, consistent with the narratives used. Projected emission

The analytical framework of the ACPR's pilot exercise (transition risk)



Source: Allen et al. (2020).
Note: ACPR – *Autorité de contrôle prudentiel et de résolution* (Prudential Supervision and Resolution Authority).

6 The NGFS has worked with a consortium of academic institutions that participate in the research efforts of the IPCC.

7 The updated scenarios in the NGFS' second iteration published in June 2021 have made available an expanded set of macroeconomic variables with NiGEM directly integrated into the NGFS suite of models, which now also provides disaggregated country-level information. Thanks to these developments, jurisdictions are able to focus on the issues involved in modelling sectoral and financial impacts, i.e. the later stages of the modelling chain presented in this document.

prices were then applied to calibrate the transition shocks associated with climate policy implementations in a macroeconomic model and in a sectoral model. As the economic data from the initial version of the NGFS scenarios lacked the granularity needed to be used by financial institutions, a **dynamic, multi-country macroeconometric model**, NiGEM, was used to replicate the NGFS' global scenarios and thus generate all the relevant macroeconomic and financial variables required (GDP, inflation, unemployment rates, government deficits and debts, etc.).

The results obtained were then used in a multi-sector general equilibrium model developed by Devulder and Lisack (2020), which breaks down the economic activity of a given country into 55 sectors of activity. The result is a **production network model**, which represents the production in each sector and in each country as a function combining energy and non-energy inputs (produced in the country or imported from elsewhere in the world) and domestic labour. It can thus be used to determine value added and turnover by sector for each scenario in a way that is consistent with the macroeconomic results provided by NiGEM.

The results from this sectoral model, when combined with macroeconomic and financial projections, informed two other modules: a **credit-risk rating module** developed by the Banque de France, which can be used to estimate firms' probabilities of default, and a financial module developed by the ACPR, which generates forecasts for asset prices, risk-free yield curves and credit spreads for each scenario and geographical region considered.

BOX 2

Physical risk scenarios

Physical risk scenarios are developed differently from transition risk scenarios as close attention must be paid to the geographical location of the issues involved, even more than the sectoral aspect. A further difficulty is that physical risk materialises during extreme climatic episodes whose occurrence and impact on human and economic activities are virtually impossible to predict.

A primary assumption of the scenarios used in the climate stress test exercises is that climate change manifests itself through more frequent and costly extreme weather events over the projection horizon. Therefore, the risk incorporated into the scenarios does not include impacts from specific weather events but reflects a gradual rising trend, rather than severe and disruptive changes. It does not entail long-term destruction of productive capacity.

In the case of the exercise carried out by the *Autorité de contrôle prudentiel et de résolution* (ACPR – Prudential Supervision and Resolution Authority), the physical risk assumptions were mainly based on the forecasts of the main contributors to the Intergovernmental Panel on Climate Change (IPCC) climate projections. For France, they were developed in partnership with the *Caisse centrale de réassurance* (CCR – the French central reinsurance fund for natural disasters), and were based on *Météo France* simulations, consistent with the IPCC RCP 8.5 scenario (see CCR/*Météo France*, 2018) and INSEE 2050 demographic projections. The exercise also incorporated the effects of climate change on the emergence of exotic viral diseases and chronic respiratory disorders linked to repeated and prolonged heat waves or increased levels of airborne particulates.

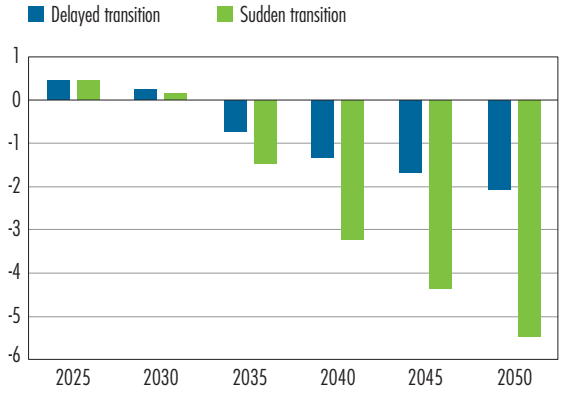
4 Moderate macroeconomic impacts, major structural transformations

Applying this framework to France showed that **the NGFS' disorderly transition scenarios would result in major economic and financial impacts**. At the aggregate level, compared with a scenario of orderly transition, simulations pointed to a GDP loss of 2.1% in 2050 in France in the event of a transition delayed until 2030. Over a period of thirty years, each annual loss would add up to substantial cumulated losses of revenue. Building on an NGFS disorderly transition scenario, the Banque de France and the ACPR put forward a more severe transition scenario, including public policy measures from 2025 onwards, and the neutralisation of the productivity gains and technological progress needed for an orderly transition. These new assumptions led to a downward revision of activity levels of around 5.5% by 2050 (see Chart 1).

These aggregate impacts mask major structural transformations and sectoral adaptations. Certain sectors would be particularly affected, causing cascade effects on the economy as a whole. **Assuming the most disorderly transition, the value added of coking and refining activities would collapse by close to 60% by 2050** compared with an orderly transition scenario (see Chart 2).

C1 Impacts on GDP in France

(% deviation from the baseline orderly transition scenario)



Source: Allen et al., 2020.

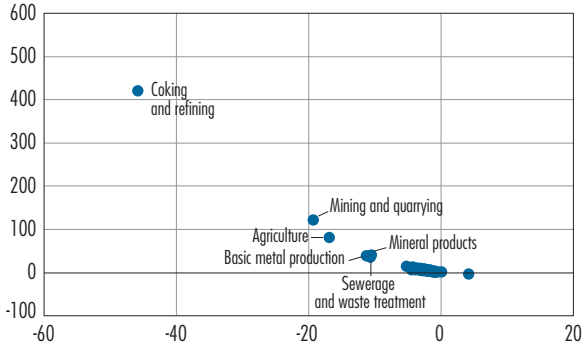
These new growth outlooks prompt market players to revise their expected returns and, if considered sufficiently likely, may lead to immediate asset value revaluations in the most affected sectors. For example, **in a delayed transition scenario, asset prices in the coking and refining sector would immediately fall by 47%** compared with an orderly transition scenario. These downward market value revisions would be even greater, at 53%, in the event of a sudden transition scenario (see Chart 3).

Credit risks should also worsen for the firms in these sectors. **In the event of a sudden transition, the**

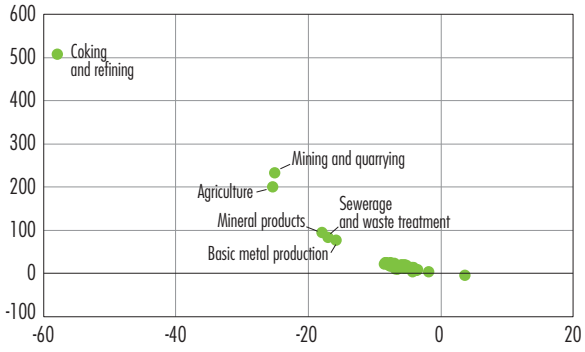
C2 Impacts on value added and probabilities of default by sector in 2050

(% deviation from the baseline orderly transition scenario; x-axis: value added; y-axis: probabilities of default)

a) Delayed transition



b) Sudden transition



Source: Allen et al., 2020.

probabilities of default (PD) would rise by a factor of six in the coking and refining sector in 2050. By way of comparison, PD deteriorated to a similar extent in the sectors most affected by Covid-19 in 2020. However, the increase in PD is gradual in the transition scenarios and spans a far longer period. In the coking and refining sector, a significant number of firms would have PD levels of over 3%, compared to just over 1.5% in the orderly scenario. In some cases, the increase would be considerable, with PD rising from 0.6% to more than 9%. This sharp increase, which represents a downgrade of four credit quality steps, would mean a significant rise in the credit risk of financial institutions exposed to those firms. This will also have very material implications with regard to asset eligibility criteria for monetary policy collateral, as the PD of collateral must not exceed 1% for it to be eligible for monetary policy credit operations.

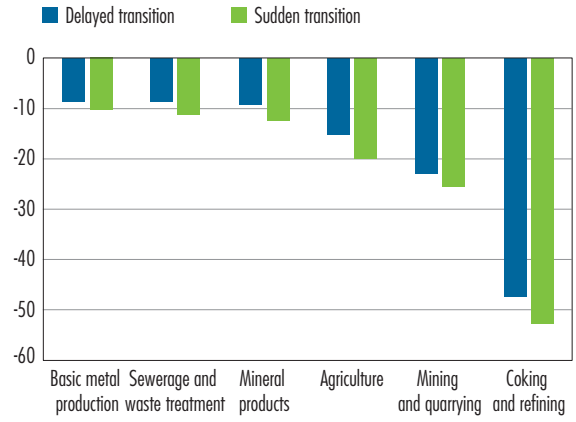
The development of climate scenarios for financial risk monitoring exercises thus meets new and specific requirements and requires supervisors and financial institutions to carry out more detailed modelling (scenarios must be broken down by sector) over longer time horizons (though climate risks can materialise in the short term, their full effects only become known in the medium and long term). However, many uncertainties remain with regard to the evolution of the climate, the transition pathway towards a carbon-neutral and climate-resilient economy and the modelling of their economic and financial implications.

Going forward, central banks and supervisors – particularly within the NGFS – will have to continue to ensure that their scenarios are aligned with the changing state of the climate and the scientific community's understanding of the dynamics at play. The most recent IPCC report explicitly states that climate change is accelerating, and its physical consequences should become more severe and could be felt sooner, with direct repercussions for financial players. This is all essential information that must now be seized upon by financial players. In addition to medium and long-term developments, these scenarios must also take into account shorter-term dynamics, as pressure is mounting for a rapid and drastic transition that could therefore be more disruptive than anticipated. Lastly, a better understanding of the impacts of transition policies on relative prices and headline inflation would be extremely useful to the monetary policy reflections of central banks.

Given these uncertainties and the progress that is still required, a degree of caution is needed when interpreting the initial results of the ACPR's pilot exercise. However, they show that despite the many methodological difficulties and the absence of certain key data, financial institutions were able to carry out assessments of the impact of climate risk. This type of exercise particularly helps to raise awareness among financial institutions on the challenges of the low-carbon transition, to improve their understanding of the transmission mechanisms of climate shocks and to speed up the integration of climate risks as financial risks into their risk assessment, monitoring and management process.

C3 Impacts of a sudden transition on value added by sector

(% deviation from the baseline orderly transition scenario)



Source: Allen et al., 2020.

References

Allen (T.), Dees (S.), Boissinot (J.), Caicedo Graciano (C. M.), Chouard (V.), Clerc (L.), de Gaye (A.), Devulder (A.), Diot (S.), Lisack (N.), Pegoraro (F.), Rabaté (M.), Svartzman (R.) and Vernet (L.) (2020)
"Climate-related scenarios for financial stability assessment: an application to France", *Banque de France Working Papers*, No. 774, July.
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Autorité de contrôle prudentiel et de résolution – ACPR (2020)
"Scenarios and main assumptions of the ACPR pilot climate exercise", July.
Download the document

ACPR (2021)
"The main results of the 2020 climate pilot exercise", *Analyses et Synthèses*, No. 122, May.
Download the document

Banque de France (2021)
Assessment of risks to the French financial system, June.
Download the document

Caisse centrale de réassurance/Météo France (2018)
Conséquences du changement climatique sur le coût des catastrophes naturelles en France à l'horizon 2050, November.

Devulder (A.) and Lisack (N.) (2020)
"Carbon tax in a production network: propagation and sectoral incidence", *Banque de France Working Papers*, No. 760, April.
Download the document

European Central Bank/European Systemic Risk Board – ECB/ESRB (2021)
Climate-related risk and financial stability, ECB/ESRB Project Team on climate risk monitoring, July.

Network for Greening the Financial System – NGFS (2021)
NGFS climate scenarios for central banks and supervisors, June.

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