MAIN RESULTS OF THE MAGYAR NEMZETI BANK’S LONG-TERM CLIMATE STRESS TEST
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IMPACT OF CLIMATE RISKS ON THE FINANCIAL SECTOR
In Hungary, 10 of the 15 hottest years in the last 120 years was after 2000.

Globally, average temperature increases by 0.12°C per decade.

ANNUAL MEAN TEMPERATURE IN HUNGARY COMPARED TO THE 1981-2010 AVERAGE

Source | Országos Meteorológiai Szolgálat (Hungarian Meteorological Service)
The number of claims has tripled in the last 40 years, while it has been above the 1980-2000 average each year.
EMERGING NEW CLIMATE RISKS

Physical risks

The weather and climate will also change significantly as a result of global warming. There will be persistent negative environmental impacts linked to climate change, such as salinisation, sea-level rise or droughts. At the same time, extreme weather events and their inherent negative anomalies, such as floods, forest fires or heat waves, are becoming more frequent. The impact of these is called physical risk in economics.

Transition risks

To reduce our emissions, the structure of the economy needs to be changed significantly. This can come partly from public actors, for example by banning certain activities or introducing carbon taxes. However, changes in preferences will also have a significant impact on firms. Both investors and consumers take increasingly in account sustainability considerations. The impact of these and the difficulty of technological transitions will also adversely affect some businesses, which will be exposed to transition risk.
IMPACT OF CLIMATE CHANGE RISKS ON BANKS

**PHYSICAL RISKS**
- Extreme weather events
- Persistent climate change
  - Impact on balance sheet
  - Impact on cash flow
  - Impact on Bank's operations

**FINANCIAL RISKS**
- Credit risk
- Market risk
- Liquidity risk
- Operational risk

**TRANSITION RISKS**
- Environmental policy changes
- Technological changes
  - Impact on balance sheet
  - Impact on cash flow
- Reputation
- Market changes

Source | DG Trésor (2017), MNB
IMPACT OF PHYSICAL RISKS ON BANKS

PHYSICAL RISK

Risk of damage as a consequence of weather events due to climate change

- Extreme weather events
  - Events having significant impact and considered unusual, unexpected and rare in the affected area
    - Impact on Bank's operations
      - Damage to, obsolescence of banking infrastructures
    - Impact on cash flow
      - Loss of client profitability, collateral depreciation
    - Impact on balance sheet
      - Devaluation of assets (e.g. securities)
  - Operational risk
    - Risks arising from the Bank's day-to-day operations (default, fraud, accidents, etc.)
  - Market risk
    - Risk arising from changes in asset prices and exchange rate fluctuations
  - Credit risk
    - The risk that the bank's client with loan may fail to perform in the manner and at the time as required by the contract
  - Liquidity risk
    - The risk that the bank may not be or may be only delayed able to meet its maturing obligations

Source | DG Trésor (2017), MNB
IMPACT OF TRANSITION RISKS ON BANKS

Transition risk from the transition to a low greenhouse gas economy due to changes in the regulatory and market environment

**Environmental policy changes**
- Regulatory measures taken to achieve the ecological objectives

**Technological changes**
- Growing role of new technologies, innovations serving ecological sustainability, increased R&D activities

**Market changes**
- Changes in consumer attitudes and demand, accompanied by an adjustment of market supply

**Reputation**
- Unfavourable external perception in case of non-adaptation to ecological requirements

**Impact on the balance sheet**
- Devaluation of assets (e.g. securities)

**Impact on cash flow**
- Loss of client profitability, collateral depreciation

**Operational risk**
- Risks arising from the Bank’s day-to-day operations (default, fraud, accidents, etc.)

**Market risk**
- Risk arising from changes in asset prices and exchange rate fluctuations

**Credit risk**
- The risk that the bank's borrower client may fail to perform in the manner and at the time as required by the contract

**Liquidity risk**
- The risk that the bank may not be or may be only delayed able to meet its maturing obligations

Source | DG Trésor (2017), MNB
ROLE OF STRESS TESTS IN IDENTIFYING RISKS
"An institution shall have a comprehensive stress testing programme for CCR (...)."

"It shall identify possible events or future changes in economic conditions that could have unfavourable effects on an institution's credit exposures and assess the institution's ability to withstand such changes."

"credit institutions shall consider the potential impact of institution-specific, market-wide and combined alternative scenarios; different time horizons and varying degrees of stressed conditions shall be considered"
STRESS TEST UNIVERSE

Top-down
Centrally defined scenario
Central data collection
Centrally performed test

Bottom-up
Central scenario supplemented even by bank scenarios
Individual bank data collection
Test performed based on individual banking models

Less involved banking sector

Coherence
Granularity

Resource intensive
The severity of the consequences based on the achievement of climate protection targets

- **Met**
  - **Disorderly**: Higher transition risk due to policies being delayed or divergent across countries and sectors.

- **Not met**
  - **Too little, too late**: Late transition fails to contain physical risks.
  - **Greenhouse Earth**: Global efforts are insufficient to halt significant global warming, leading to severe physical risks.

**Orderly**
Climate policies are introduced early and become gradually more stringent.
COUNTRIES THAT HAVE SIGNED AND RATIFIED THE PARIS CLIMATE AGREEMENT

By November 2021, signed by 195 countries, ratified by 193 countries

- The main objective is to keep the global temperature increase below 1.5-2°C.
- This requires a rapid reduction in GHG emissions.
- The Agreement provides the basis for orderly transition in climate stress scenarios.

Source | United Nations Treaty Collection, MNB
A model that can translate the evolution of global warming drivers (e.g. greenhouse gas concentrations in the atmosphere) into economic consequences, all at sectoral level, as the involvement of different activities can vary considerably, addressing the two-way feedbacks between natural and economic variables, as economic measures affect the evolution of natural variables.
CAMBRIDGE ECONOMETRICS E3ME MODEL
Econometric model with complex system of equations: global economy (61 countries/regions: 33 European, 28 other), environmental impacts and energy market, with two-way feedbacks.

Data with annual frequency starting from 1970 projected until 2050

Source | CE, MNB
The assumption is that supply catches up to the demand.

It allows imperfect capacity utilisation, which is also the typical condition.

Regulatory and policy measures can boost investment, employment etc. and ultimately the output.
Failed Transition
No additional decarbonization efforts

- Continuation of EU ETS
- Phase out of fossil fuel subsidies (EU, USA, China, Japan)
- Renewables mandates (China, Germany, UK)
- Ongoing (but declining) investment to coal power generating
- Biofuel blending mandates in India and USA

Orderly Transition
Aligning with Paris Agreement

- Ambitious carbon pricing
- Economy-wide energy efficiency programs
- Decreasing demand for fossil fuels, deteriorating economic environment for the related companies
- Direct renewables subsides
- Preventing investment to coal power generating
- Phasing out ICEs

Disorderly transition
Alignment with PE with delayed risk pricing

- The regulatory environment is the same as in orderly transition (differing from the NGFS ‘disorderly transition’ scenario)
- However, it is only after 2025 that financial markets will price climate risks in a swift manner
- Physical risk remain at the level of orderly transition
Ambitiously increasing carbon pricing could generate significant government revenues.

Assumption: The government’s net revenue from carbon tax is zero; consumption tax revenues are decreased at the amount of raised carbon tax revenues.

Reducing tax burden on consumer goods creates a consumption stimulus (in a competitive environment).

The consumption stimulus leads to a general stimulus in a demand-driven model (with spare capacity).

Source | CE, MNB
If the transition fails, global CO₂ emissions will gradually increase until the end of the century. With an orderly transition, net zero CO₂ emissions will be reached by 2070.

Compared to pre-industrial times, i.e. the second half of the 19th century, in the case of a failed transition, the Earth's average temperature would increase by 3.5-4 degrees Celsius. If the commitments made in the Paris Agreement are met, global temperature increase will be kept below 1.5 degrees Celsius by the end of the century.

Source | CE, MNB
• The Climate-Uninformed Baseline (CUB) represents the imaginary trajectory of failed transition free of physical risks.

• For the world as a whole, even a 1.5-2 degrees Celsius trajectory has negative consequences.

• However, there is a wide variation among countries, not all of them are (directly) affected by sea-level rise, for example.
IMPACTS OF CLIMATE SCENARIOS ON THE HUNGARIAN ECONOMY
In case of a failed transition, GDP levels are expected to be 4-4.5 percent lower by the end of 2050 due to the physical consequences of climate change. But the way to get there is just as important, because it is not a one-off negative shock in the distant future, but the fact that compared to the hypothetical baseline trajectory, there will always be less goods to be shared.
In orderly transition, the physical impacts will be significantly reduced as global temperature increases more moderately. For the Hungarian economy as a whole, the transition is not a risk but an opportunity, as it will entail surplus in GDP. From a domestic perspective, a world transited to "climate-friendly" operation is therefore highly desirable.
According to the schedule, two new units of Paks II will be started and two existing units will be phased out.

Coal and lignite power plants will be phased out.

Solar energy becomes the preferred and subsidised renewable resource.

The Hungarian orderly transition scenario was developed by Cambridge Econometrics based on the 2019 National Energy and Climate Plan published by the Department of Innovation and Technology.
TRANSITION “RISKS”: INVESTMENT AND NET EXPORT AS MAIN BOOSTERS

DECOMPOSITION OF GDP EFFECTS OF TRANSITION RISKS (ORDERLY TRANSITION, DEVIATION FROM CUB LEVEL)

Source | CE, MNB
Greening energy production

- Investments in key infrastructures that are to be decarbonized, i.e. energy production and transportation, are booming.
- These investments will stimulate the construction, metalworking and electronics manufacturing sectors.

Transition of the automotive industry

- The transition of the automotive industry to more fuel-efficient or electric technologies is also driving investment and net export in related sectors.
- The situation of the sectors extracting and using fossil fuels is deteriorating.

Household’s disposable income increase

- The improvement in the external trade balance also due to reduced imports of fuels increases the income that can be spent on other products.
- The increase in disposable income is mainly boosting output in the agricultural, food industry and consumer goods sectors.

Source | CE, MNB
The variable set shows the set of independent (not derived from each other) variables.

Physical risks were only available for gross value added (GVA).

This has given rise to unconventional solutions when using time series.
A – AGRICULTURE, FORESTRY AND FISHING
   01 Crop and animal production, hunting and related service activities
   02 Forestry and logging
   03 Fishing and aquaculture

B – MINING AND QUARRYING
   05 Mining of coal and lignite
   06 Extraction of crude petroleum and natural gas
   07 Mining of metal ores
   08 Other mining and quarrying
   09 Mining support service activities

U – ACTIVITIES OF EXTRATERRITORIAL ORGANISATIONS AND BODIES
   99 Activities of extraterritorial organisations and bodies

The variables provided by Cambridge Econometrics refer to the aggregated groups of 99 NACE level 2 nomenclature (mostly level 1 categories).
METHODOLOGY AND KEY RESULTS OF THE MNB'S LONG-TERM STRESS TEST
FOCUSING ON NPL RATIO

NPL ratio = \frac{\text{loans with 90+ days past due}}{\text{all loans}}

Definition of loan:
• Loans, credits, credit type agreements, financial leases (both on- and off-balance sheet items)
• provided by other monetary financial institutions (MNB sector code C)
• to non-financial corporations with a Hungarian tax number (≈ with NACE classification).
FOCUSING ON NPL RATIO

A key indicator of financial stability (loan quality) 3.

There is empirical evidence of its connection with the cyclical situation. 4.

Relatively less dependent on bank decisions compared to other key variables (e.g. earnings, write-offs, capital). 5.

Sales to factoring companies were small compared to the banking system in the examined time period. 6.
**Goals of modelling**

Conditional forecast of the target variable (NPL ratio) over the time horizon 2020-2050, on the basis of the economic environment already modelled in each scenario.

A total of 54 conditional forecasts:
- For 3 scenarios: failed, orderly and disorderly transition trajectories.
- For 18 sectors: covering the whole economy.

**Model estimation**

Historical relationship between sectoral NPL ratios and (already forecasted) sectoral economic variables.

- 'Training' time window is relatively short: 2012Q2 to 2019Q4.
- Use of unified models for all sectors.
  - Same function form and variable set (GVA, ULC, etc.).

**Forecast**

By feeding trajectories of economic variables into estimated models.

- Underlying assumption: the estimated parameters are stable over time.
- Physical and transition risks are concentrated in a single variable.
  - Different GVA trajectories underlie the different NPL ratio projections of scenarios.
A single model in each sector

\[ NPL_t = \beta_0 + \beta_1 I\text{gap}_t + \beta_2 X\text{gap}_t + \beta_3 ULC\text{gap}_t + \beta_4 GVA\text{gap}_t + \varepsilon_t \]

1. \( NPL_t \): NPL ratio

2. Explanatory variables: transformants of interpolated variables
   - Frequency conversion from annual to quarterly (Denton-Cholette).
   - 'Gap': ratio of deviation from own CUB trend (univariate HP filter)

3. Default estimation method: OLS.
   - In case of negative NPL ratio forecast, TOBIT (for 2 sectors).

4. Unconventional modelling decisions (frequency conversion, gap instead of lagging) are due to the shortness of the NPL time series.
Assumption on the GVAgap in the forecast:

\[ GVAgap = \left( GVA^{scen} - GVA^{cub\ trend} \right) / GVA^{cub\ trend}, \]

where \( scen \) denotes OT, DT and HT scenarios, and \( cub \) denotes the climate-uninformed hypothetical scenario.

1. Point forecast of NPL ratio is prepared for three scenarios per sector.

2. The excess of the failed and disorderly transition scenarios compared to that of orderly transition are reported.

3. We also monetise this excess on the basis of loans in 2019Q4, assuming its static composition.
RESULTS: EXCESS RISK OF FAILED TRANSITION

- The non-payment outlooks show high dispersion over time.
- The differences are due to different physical and transition risks and different cyclical sensitivity.

The values show the difference between two scenarios.

EXCESS NPL RATIO (BENCHMARK: OT)

Values of asterisked sectors are statistically insignificant.
RESULTS: ABSOLUTE VALUE OF THE ADDITIONAL RISK OF FAILED TRANSITION

- The values presented are based on the static loan portfolio of 2019q4.
- Significantly different pairs of sector risk and exposure may, of course, be behind similar values.

The values show the difference between two scenarios.

Values of asterisked sectors are statistically insignificant.

EXCESS NPL IN HUF

Source | MNB
The excess NPL of failed transition is nearly half a trillion forints.

This is a rough underestimate due to the assumption of static portfolio.

By dynamizing sectoral loans with sectoral GVA growth, the total excess is about 50 percent higher.

! The values show the difference between two scenarios.

### Total Excess NPL of Failed Transition

<table>
<thead>
<tr>
<th>Source</th>
<th>MNB</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EXCESS NPL IN BILLION HUF</strong></td>
<td><strong>TOTAL EXCESS NPL OF FAILED TRANSITION</strong></td>
</tr>
<tr>
<td>2030q4</td>
<td>151</td>
</tr>
<tr>
<td>2040q4</td>
<td>240</td>
</tr>
<tr>
<td>2050q4</td>
<td>466</td>
</tr>
</tbody>
</table>

Billion HUF (2019Q4 prices)
RECOMMENDATIONS FOR THE FINANCIAL SECTOR
The current stress test is a pilot project. Its primary objective is to draw the attention of financial sector to the risks and opportunities inherent in climate risks. Through this work, the MNB also aims to promote knowledge building and remains open to knowledge transfer. The information and analysis provided can help to understand the scale and distribution of the risks posed by the new challenges. Although the analysis has a micro-prudential focus, it is not intended to determine capital requirements.
Comparing the average temperature trajectories of the IPCC Synthesis Reports 5 and 6, as shown in the figure, the projections can vary over time, but typically show a more pessimistic picture.

Average temperature increase for the period 2081-2100 calculated for each scenario compared to the average temperature increase for the period 1850-1900, in degrees Celsius. The figure shows the forecast bar and point estimate for Synthesis Report 5 (RCP) on the left and for Synthesis Report 6 (SSP) on the right, for each scenario.
TRANSITION RISK IS ALSO AN OPPORTUNITY

While there will be victims in the transition to a green economy, the process also offers unique opportunities. According to the model of Cambridge Econometrics, the Hungarian economy is a clear winner of the transition, thanks to e.g. falling energy imports. By becoming pioneers in certain industries, the export capacity of Hungarian companies will also improve significantly. A positive example is the significant investments made by Hungarian water companies in South East Asia and Africa, as well as the establishment of solar parks and solar power plants by several Hungarian companies in neighbouring countries.
Sustainability is a priority for sectors that are particularly exposed to climate risks. It is important to emphasise that the results of the long-term climate stress test do not imply that financing the most vulnerable sectors inevitably carries significant additional risk for credit institutions, but that in order to minimise this, the sustainability dimension of these projects should be taken into account.

Significant investment is needed to mitigate physical and transition risks, in which credit institutions are – optimally – partners. This is in the interest of both parties.
DEVELOPMENT DIRECTIONS
IMPROVEMENT OF DATA ASSETS

- Use of granular data
- Extending data reporting with sustainability objectives
- A deeper and more accurate knowledge of the companies that received loans
- Modelling management decisions
There are a number of transaction-level databases available to Magyar Nemzeti Bank, which can be used to further refine the results of the long-term climate stress test. However, their use poses a number of challenges, such as limitations on the usability of data provided by peer authorities. Other challenges include the low frequency, changing composition, high manuality of improving, as well as the extreme human resource-intensity of data reporting.

In relation to recognising the importance of data, a number of transaction- and client-level databases have been created, however, currently there are no long enough time series to produce 30-year forecasts. The MNB aims to include new sources of data in the next implementation, such as an analysis of the energy efficiency of commercial real estate or a detailed analysis of the location of the registered offices and premises of companies.
The former design of several frameworks and databases did not prioritise meeting the needs of sustainability analysis. One of the most striking examples is the NACE sector breakdown. Within sector code D (electricity, gas and steam supply, air conditioning), the source of electricity generation is not specified, i.e. solar and coal-fired power plants are included in the same sector, although there is a significant difference between the two energy suppliers from a climatic and therefore credit risk point of view. The MNB will therefore also label green loans in its credit databases.
Experience to date and consultations with credit institutions have highlighted the need for a more accurate mapping of the businesses that received loans. The NACE codes indicated as the main activity are often inaccurate. Many credit institutions do not know the exact location of the registered office and premises of the companies they lend to. To make full use of these data, significant data cleaning will be required during the next stress test. A further difficulty is to assess the scope of activities of certain holdings and to track mergers.
With the long-term climate stress test, the MNB has taken the initiative step in assessing the physical and transition risks. At the same time, credit institutions are expected to assess these risks and, after modelling the risks, to develop their management actions and adequate responses. Action plans will be reviewed and modelled quantitatively by the MNB to allow the identification of risks at the institution level. In the future, it assess the further improvement possibilities of the stress test along these efforts.

In the coming years, the financial sector’s task is to assess the risks inherent in climate change and the economic potential of facilitating sustainability. The MNB will always be a partner to institutions, through recommendations, incentive programmes and knowledge transfer, supporting the financial sector in reducing its transition risk, while expecting responsible behaviour.
Quantifying the exposure of retail products to climate change and transition risks is an even greater challenge for authorities as compared to corporate clients. The MNB is also planning to include this segment, and thus modelling the entire client base, i.e. to follow a more comprehensive approach of financial stability.