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Feeling the Heat: Mortgage Lending and Central Bank Options*

Eszter Baranyai – Ádám Banai

Extreme heat periods due to the changing climate are having a negative impact on many areas of the economy. In our study, we look at how much US mortgage lending is originated in the areas that are most vulnerable to future heat waves, and what central bank and supervisory authority actions could mitigate the resulting risk. From our results, we see that proportionally more lending flows into the areas that are likely to be most exposed to heat in the future. Population and economic output are relatively higher in these areas, and thus climate risk is less of a factor in lending decisions. However, lenders reject proportionately slightly more mortgage applications in the counties that are expected to be the hottest. Central bank and supervisory authority measures to support climate objectives are therefore of key importance. These could include, for example, central bank asset purchase programmes to support sustainable construction, especially in areas vulnerable to climate change, or the development of collateral management along similar lines. Coordination between the different authorities is also important because of the limitations of central bank actions.

Journal of Economic Literature (JEL) codes: E58, G21, Q54

Keywords: climate change, heat, mortgage lending, USA, central bank, supervisory authority

1. Introduction

Climate change is one of the greatest economic and social challenges of our time. According to climate scientists, there are a number of phenomena around the world that have not been seen in the past thousand, or even several thousand years.[1] Some of these are already irreversible. As average temperatures rise, heat days are

* The papers in this issue contain the views of the authors which are not necessarily the same as the official views of the Magyar Nemzeti Bank.

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[1] *Climate change widespread, rapid, and intensifying – IPCC*. Press Release, Intergovernmental Panel on Climate Change, 9 August 2021. https://www.ipcc.ch/site/assets/uploads/2021/08/IPCC_WGI-AR6-Press-Release_en.pdf. Downloaded: 8 February 2022.

becoming more and more frequent,[2] and they are harmful to both the economy and the human body. We also see changes in the water cycle. In addition to rising sea levels and retreating ice caps, the shift towards extremes should be highlighted, such as the increasing frequency of intense precipitation and droughts.

The relationship between the financial sector and climate change is complex and multifaceted (*FSB 2020*). On the one hand, through their financing activities, financial system actors can have an indirect impact on the process of climate change, depending on how environmentally sustainable their activities are (*Boros 2020*). On the other hand, climate change will not leave the financial sector untouched (*FSB 2020*). If climate risk is not sufficiently priced in – and the authorities responsible for financial stability have repeatedly voiced concerns about this[3] – possible rapid repricing events could have negative effects on the prices of a wider range of financial instruments and the stability of market participants. The sudden repricing and increase in risk premia may be due to a reassessment of physical risks, but may also reflect the temporary instability caused by the transition to a low-carbon economy.

These findings also apply to mortgage lending. Properties exhibit large differences in terms of their environmental impact (*Lützkendorf 2018*). Location is key in this respect as well. The environmental footprint of a building and the financial cost of its operation can also vary significantly from one location to another, and in the light of climate change, the question is how well the characteristics of buildings financed by mortgage lending today match the future climate of the area.

In many US states, housing construction rates are up to two to three times higher in zones which are at risk of flooding due to rising sea levels as compared to less at-risk neighbourhoods (*Climate Central 2019*), even though protecting against sea level rise is difficult and costly (*Leatherman 2018).* In addition, construction in such areas increases the risk of flooding, as the weight of buildings can cause tangible subsidence of the ground surface (*Parsons 2021*).

Central banks are also increasingly recognising that climate change may also have a negative impact on price stability and financial stability – i.e. fundamentally affect the goals set out in the central bank mandate.[4] Going beyond this, in Hungary the mandate of the Magyar Nemzeti Bank (the central bank of Hungary, MNB) already includes the promotion of environmental sustainability as a statutory goal (*MNB 2021a*).

[2] Climate Change Knowledge Portal. World Bank Group. https://climateknowledgeportal.worldbank.org/. Downloaded: 11 February 2022.
[3] Carney, M.: *Breaking the Tragedy of the Horizon – climate change and financial stability*. Speech given at Lloyd's of London, 29 September 2015. https://www.bankofengland.co.uk/speech/2015/breaking-the-tragedy-of-the-horizon-climate-change-and-financial-stability. Downloaded: 30 September 2021.
[4] Lagarde, C.: *Climate Change and Central Banks: Analysing, Advising and Acting.* Speech by the President of the ECB at the International Climate Change Conference in Venice, 11 June 2021. https://www.ecb.europa.eu/press/key/date/2021/html/ecb.sp210711~ffe35034d0.en.html. Downloaded: 30 September 2021.

In this study, we look at US mortgage lending in areas subject to future heat waves. We study US data for reasons of detail and availability, and because in a country of this size there can be significant differences in the exposure of different areas to climate change. Precisely for this reason, the undoubtedly complex regional economic dilemmas of whether it is worth it to influence the spatial distribution or conditions of mortgage lending, and if so, how may be more relevant. Much of the literature has so far focused on real estate markets in flood risk zones, with little attention paid to real estate markets in areas exposed to future extreme heat. Previous studies have examined, among other things, the price effect (*Baranyai – Banai 2021*) or the impact on securitisation (*Baranyai 2021*), but, to the best of our knowledge, the relationship between extreme temperatures and the volumes of (mortgage) lending has not been studied in the literature.

In our study, we would like to draw attention to the fact that spatial inequalities in lending can also be examined from a climate change perspective, and that the options available to decision-makers should also be assessed from this perspective. Our analysis is mainly based on descriptive statistics – partly due to the nature of the research questions and partly to the lack of complete data – and lays the ground for further research that could, for example, explore the relationship between climate change and the denial of mortgage/loan applications in more detail.

Our research questions are the following:

1. Are more mortgages disbursed in counties in the US that are most vulnerable to future heat waves, relative to their land area, economic importance and population?

2. What do we know about supply and demand effects in lending patterns?

3. What can the central bank do to better understand and mitigate the climate risks associated with heat waves?

2. Overview of the literature

The analysis of our study is based on the theoretical assumption that heat can have negative economic, social and financial stability effects, and thus it is unfortunate to have a disproportionately high volume of mortgage originations in the most heat-prone areas. The negative economic and health impacts of heat are well documented in the literature. *Zivin – Neidell* (*2014*) detect lower labour productivity, *Jones – Olken* (*2010*) lower industrial output, *Addoum et al.* (*2018*) lower corporate profits, and *Dell et al.* (*2012*) and *Burke et al.* (*2015*) lower aggregate economic growth in the case of high temperatures. *Hajat et al.* (*2010*) found a relationship between extreme temperatures and higher mortality and morbidity, and *Deschênes*

and Greenstone (*2011*) point out that the relationship is not linear, i.e. extreme increases need special attention. It is therefore not ideal, neither economically nor socially, to encourage construction and increased human and economic presence through mortgages in the places most exposed to extreme high temperatures.

The literature suggests that actors in the financial system are not sufficiently taking into account the risk of climate change, which may in turn raise financial stability concerns. In the real estate market, the expected temperature increase and the impact of extreme temperatures have not yet been studied, but sea level rise has. Several studies have demonstrated a small price effect (*Bernstein et al. 2019; Baldauf et al. 2020*), although some have found no such correlation at all (*Murfin – Spiegel 2020). Baldauf et al.* (*2020*) found that the extent of the price effect varies by area. Overall, the research results suggest that even in the case of sea level rise, it cannot be said that the risk is fully incorporated into real estate prices, which is probably also true for a less tangible risk (higher heat).

To reduce their risks, lenders can resort to various strategies which could also reduce the risk of instability in the financial system. The literature mainly focuses on whether a contemporary event related to climate change will induce lenders to change their behaviour. Here too, the picture is mixed. According to *Garbarino – Guin* (*2021*), for example, British credit institutions did not change any of the parameters studied after the 2013–2014 floods. However, *Duan – Li* (*2019*) find evidence that US lenders disburse less loans in areas that experience extreme heat today. The authors attribute this to a change in loan officers' expectations regarding climate change. *Ouazad – Kahn* (*2019*) found evidence that after natural disasters, the possibility of further disasters becomes more prominent in the minds of lenders. And at such times, they are even more eager to transfer this risk to companies closely linked to the state that support the US real estate market (government-sponsored enterprise: GSE).

Few studies have specifically examined the relationship between retail mortgage lending and future heat expectations, but their (preliminary) results suggest that at the aggregate level, lending behaviour is not independent of climate risk. According to *Baranyai and Banai* (*2021*), the more exposed a US area is to future heat, the higher the interest rate on local retail mortgages. The effect is a few basis points and is more significant in areas most exposed to extreme heat. *Baranyai* (*2021*) detects higher securitisation rates in these areas – which can be interpreted as lenders transferring part of their climate risks to the GSEs.

In the present study, we first investigate whether or not a proportionately large amount of credit flows to the places most exposed to heat waves. We are not aware of similar studies examining the relationship between future heat and volume of (mortgage) lending, but there have been other forward-looking analyses that

examined the volume of today's activities in terms of climate exposure. The most relevant example is the analysis of housing construction rates according to flood risk exposure (*Climate Central 2019*), also taking into account the climate scepticism of people living in areas exposed to climate change (*Barrage – Furst 2019*).

Our analysis focuses on the macro-level decision-making perspective, including that of the central bank, and is thus related to the literature on the policy direction of climate finance. One of the key focuses of climate finance is financing the transition to a low-carbon, sustainable and climate-resilient economic model. Decision-makers around the world have already introduced measures that can be classified in this category; their effectiveness is evaluated by *Bhandary et al.* (*2021*). For an international perspective on the use of central bank toolkits in the context of climate change, see *MNB* (*2019; 2021a*); the potential role of central banks in the development of the green bond market is discussed by *Mihálovits and Tapaszti* (*2018*), while the challenges facing central banks and supervisory authorities in the context of climate change are discussed by *Campiglio et al.* (*2018*). They show that central banks are typically at the beginning of their journey towards risk management, and green aspects are emphasised mostly in their communication. As a first step, *Campiglio et al.* (*2018*) propose the development of a broad framework for risk mapping. So far, the US Federal Reserve has been amongst the central banks seeking to deepen its understanding of the risks, but looking ahead it is possible that there will also be measures to increase the climate resilience of the financial system (*Brainard 2020*). The MNB is now actively mainstreaming green considerations into both its supervisory and monetary policy toolbox, which makes it one of the pioneering central banks.

Possible central bank actions may differ depending on whether it is borrower or lender behaviour that underlies a particular territorial pattern of lending, and so we will examine this. However, it is beyond the scope of this article to establish in detail the extent to which the behaviour revealed is the result of a conscious attitude related to climate change.

3. Data and methodology

The most comprehensive publicly available database covering mortgage lending in the US is the Home Mortgage Disclosure Act (HMDA) database. It was created by the US Congress decades ago to help track how well lenders are serving the housing needs of local residents, to uncover potential discrimination and to help allocate public investments across the country (*FFIEC 2021*). Most banks and non-bank financial service providers engaged in lending are required to report HMDA data, with the exception of a few small institutions, mainly in non-metropolitan areas, which are not engaged in mortgage lending. The financial literature makes

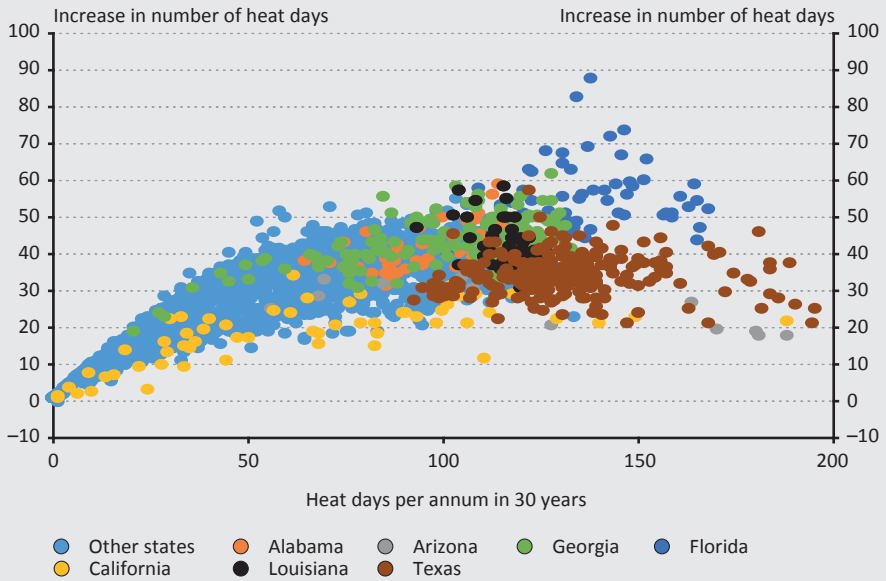
extensive use of this database (*e.g. Duan – Li 2019*). We also rely on this loan-level database for data related to US lending volumes, the characteristics of borrowers and lenders, as well as the loan-to-income (LTI) ratio.

The work of international climate research groups has been coordinated by the Coupled Model Intercomparison Project 5 (CMIP 5), and the arithmetic mean of the projections produced is also quoted in UN publications. A higher-resolution, US-wide version is available from the National Oceanic and Atmospheric Administration Applied Climate Information System (ACIS) database. We also use this database and its climate change projections.

Land area and population data are from the US Census Bureau, and regional economic performance data are from the Bureau of Economic Analysis. The survey is conducted at the county level by aggregating micro-level loan contract data. Our study does not cover Alaska and the so-called US territories (islands that are not linked to the US states).

Within climate change, we focus on the number of extremely hot days, when the daily maximum temperature exceeds 90°F, or 32.2°C. This cut-off value is also used in the ACIS database. We distinguish between future *levels* (the average of projections for 2041–2050) and the *change* compared to the most recent data (the difference between the average of 2041–2050 and the average of 2003–2012). Although our two heat variables are highly correlated, the highest increases in heat days are not always expected in the counties that are at the top of the heat list today. In some counties in California and Texas, for example, the projected increase is not outstanding, but they will nevertheless be among the hottest counties because they are already there (*Figure 1*). The number of heat days is forecast to increase most in the south-eastern part of the US (Florida, Georgia, Alabama, etc.).

Figure 1
Increase in the number of heat days and their future level



Note: Each dot represents a county. The X-axis shows the future level of heat (>90°F) days (average of projections for 2041–2050), while the Y-axis shows the projected change in the number of heat days (the difference between the averages of 2041–2050 and of 2003–2012). The counties in the states most exposed to future heat (either by X or Y heat variables) are highlighted in a different colour.

Source: ACIS

In the first part of the analysis, we compare the volume of disbursed loans and loan applications (flow) with population, GDP and land area data according to the area's exposure to heat (looking at both the level and the change). For lending data, we examine "vanilla" mortgages.[5]

In the second part of the analysis, loan denials rates will be constructed. The simple denials rate is the ratio of denied loan applications to the sum of disbursed loans and denied loan applications. This is used, for example, by *Duan and Li* (*2019*). We calculate rates based on both the volume of (mortgage) lending (flow) and the number of loan applications. We then generate sophisticated denials rates based on *Keys and Mulder* (*2020*), with the aim of filtering out the effects of known characteristics of loan applications and lenders. The following equation is used for loan application *i*, in county *j* and year *t*:

[5] The lending purpose is, for one (not more than one) family, to purchase or refinance a home; not for commercial purposes; no guarantee from the Federal Housing Administration, Farm Service Agency, US Department of Agriculture Rural Housing or Veteran Benefits Administration; the loan has no non-amortising features; the mortgage is not open-end or reverse.

$$
\begin{aligned}
Denial_{i,j,t} = \alpha + \beta_{j,t} CountyYearDummy_{j,t} + \beta_1 Loan\ amount_i + \beta_2 Loan\ amount_i^2 \\
+ \beta_3 LTI_i + \beta_4 LTI_i^2 + \beta_5 \left(CLL_{j,t} - Loan\ amount_i\right) \\
+ \beta_6 \left(CLL_{j,t} - Loan\ amount_i\right)^2 + \beta_7 Ethnicity1_i \\
+ \beta_8 Ethnicity2_i + \beta_9 Ethnicity3_i + \beta_{10} Gender\text{-}dummy1_i \\
+ \beta_{11} Gender\text{-}dummy2_i + \beta_{12} Owner\text{-}occupied_i \\
+ \beta_{13} Local\ lender\ dummy_i + \epsilon_{i,j,t}
\end{aligned}
\tag{1}
$$

Denial is a dummy variable with a value of 1 indicating denial of the application. CLL means the county and year-specific loan contract level cut-off value above which the GSEs will no longer purchase loans. LTI is the ratio of the loan amount to income. From demographic characteristics, we also take into account the ethnicity (White, Asian, Black, Hispanic) and gender (male, female, or male and female combined) of the loan applicant. This is important because, although we do not have information on debtor classification, it may correlate with certain characteristics, and skin colour, for example, may also play a role in the lender's decision – this is partly the reason why the HMDA database was set up (*FFIEC 2021*). Other control variables include the loan amount, the square of the loan amount and a dummy variable indicating whether the owner lives in the property. Finally, the literature suggests that lender behaviour may be affected by whether the lender is considered local, so we construct a dummy variable for this defining a lender as local in line with *Keys and Mulder* (*2020*) if it disburses at least 10 per cent of its annual lending in the county.

To construct the rejection index, $\beta_{j,t}$ values are added to the average denials rate calculated from the data so that the index values are between 0 and 1. Thus, our index is a measure of how application denials have evolved across counties and years, beyond the known loan-level characteristics. Data was available from 2017 to 2019.

Our key variables are summarised in *Table 1*.

Table 1
Main variables

Variable	Observations	Average	Standard deviation	P1	P25	Median	P75	P99
Number of heat days in 30 years	3,067	67.07	39.44	2.34	35.23	62.67	98.19	163.23
Increase in the number of heat days	3,067	29.9	11.83	1.59	21.98	31.91	38.03	55.51
Lending vs. territorial share	3,067	0	0.16	–0.2	–0.03	–0.02	–0.01	0.52
Simple denials rate (sum)	28,808	0.15	0.08	0.02	0.09	0.13	0.18	0.45
Sophisticated denials index	9,197	0.18	0.07	0.03	0.14	0.17	0.2	0.45

Note: The simple denials rate is for the years 2010–2019, while the sophisticated denials index is for the years 2017–2019.

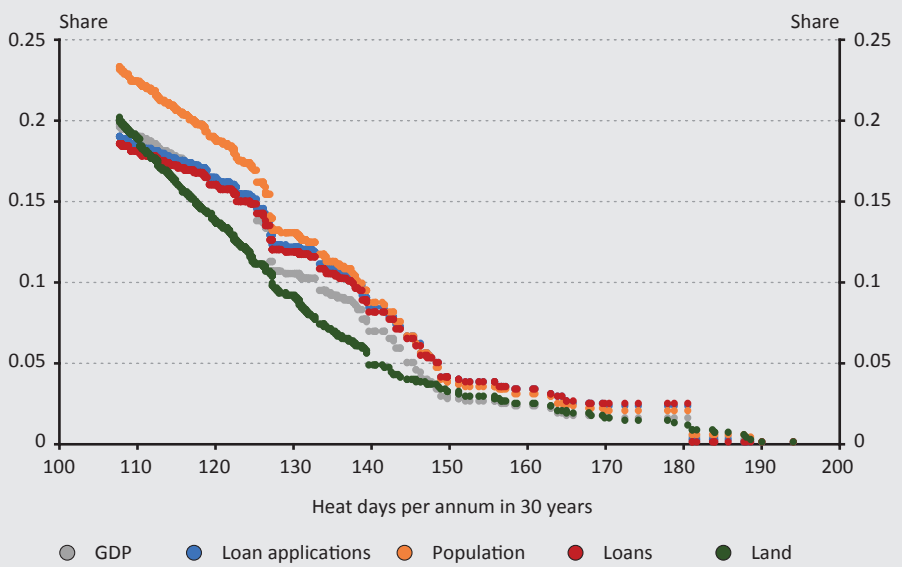
Source: ACIS, HMDA

4. Data analysis

4.1. Volume of (mortgage) lending and loan applications

The spatial distribution of the population and the country's economic performance is uneven. 13 per cent of the US population, 11 per cent of economic output and nearly 12 per cent of mortgage lending is tied to areas that will be in the hottest 10 per cent in 30 years (*Figure 2*). Similarly, areas that are expected to experience at least 140 heat days in the future, putting them in the hottest 5 per cent based on their land area, account for 7 per cent of total economic GDP and 8–9 per cent of population and loans disbursed (*Figure 2*). Focusing on the change in heat days over the next three decades, rather than future heat, gives a similar picture. The 5 per cent of the country's area with the highest projected increase in heat days covers 9 per cent of the country's population, 7 per cent of disbursed loans and 7 per cent of GDP (*Figure 3*).

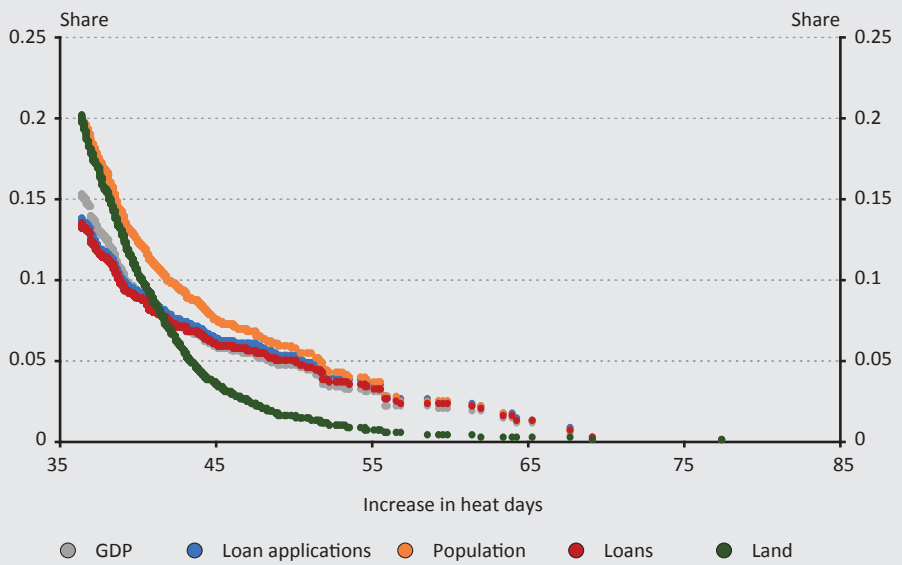
Figure 2
Mortgage lending in the area as a function of the number of "hot" days expected in 30 years – extremes



Note: The figure shows the share of the country's disbursed loans, population, GDP, loan applications and land area in 2019 that were in counties where x or more heat days (>90°F) are expected in 30 years (average of 2041–2050).

Source: ACIS, HMDA, US Census Bureau, BEA

Figure 3
Mortgage lending as a function of the expected warming of the area – extremes



Note: The figure shows the share of the country's disbursed loans, population, GDP, loan applications and land area accounted for by counties with x or more increase in the number of heat days (> 90°F) over the next 30 years (average of 2041–2050 minus the most recent historical data: average of 2003–2012).

Source: ACIS, HMDA, US Census Bureau, BEA

The question is whether the pattern is driven by a few (large) counties, or the statement is true for a wide range of counties. To answer this question, we first compare the territorial share of a county with its role in lending (*Table 2*, variable E). *Table 2* shows the counties with the largest difference in either direction. In particular, California's affluent regions benefit from a higher volume of lending relative to their land share, with the sparsely populated western US counties at the bottom of the list.

Table 2
Where does the role in lending differ most from the importance of land area?

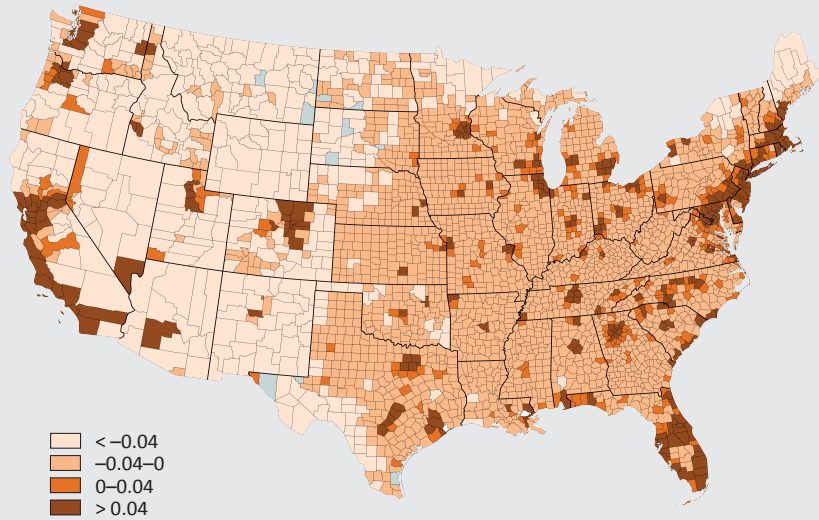
County	Share of county (per cent)				Lending % – Area %	Population % – Area %	GDP % – Area %
	Lending	Land area	Population	GDP			
	A	B	C	D	E = A – B	F = C – B	G = D – B
Highest volume of lending in relation to share of land area							
Los Angeles County, CA	4.95	0.14	3.08	3.87	**4.81**	2.94	3.73
Orange County, CA	2.36	0.03	0.97	1.27	**2.33**	0.95	1.25
Santa Clara County, CA	2.04	0.04	0.59	1.57	**2.00**	0.55	1.52
Maricopa County, AZ	2.24	0.31	1.38	1.25	**1.92**	1.06	0.93
San Diego County, CA	1.99	0.14	1.02	1.20	**1.84**	0.88	1.05
Lowest volume of lending in relation to share of land area							
Humboldt County, NV	0.00	0.38	0.02	0.01	**–0.38**	–0.36	–0.37
Malheur County, OR	0.06	0.45	0.07	0.03	**–0.40**	–0.39	–0.43
Inyo County, CA	0.01	0.59	0.02	0.01	**–0.58**	–0.57	–0.57
Harney County, OR	0.06	0.63	0.04	0.04	**–0.58**	–0.59	–0.60
Sweetwater County, WY	0.01	0.62	0.01	0.01	**–0.61**	–0.61	–0.61

Note: In line with the focus of the study, the calculations exclude Alaska and the islands not connected to the US (Territories of the United States) as well as 12 additional counties due to data limitations. CA: California, NV: Nevada, OR: Oregon, WY: Wyoming

Source: ACIS, HMDA, US Census Bureau, BEA

The difference between lending and territorial shares (variable E in *Table 2*) is also depicted on a map (*Figure 4*). We can see that, in addition to some counties in California, there is more lending in the northeast coastal region, Florida and around some large cities, relative to their area. It is also striking that this value is generally lower in the western half of the country. A similar pattern can be recognised in the population importance of counties (*Figure 5*; this is variable F in *Table 2*) and in the economic importance of counties (not shown separately in the study, variable G in *Table 2*). The relationship will be explored more formally below.

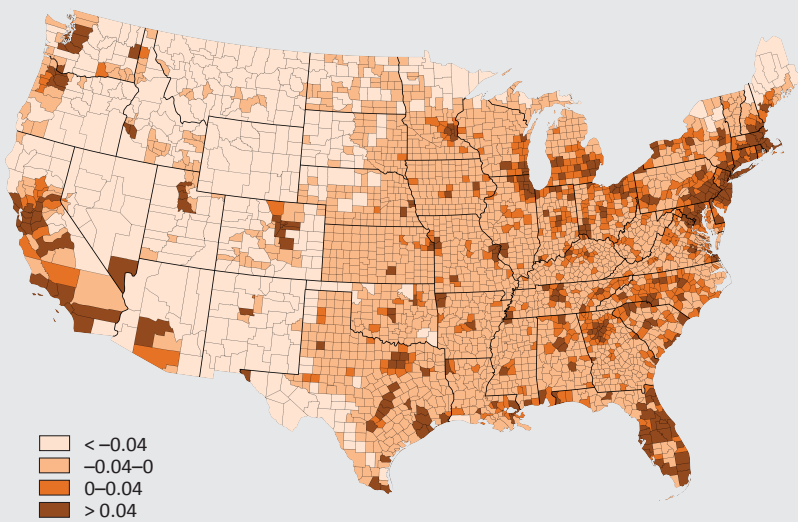
Figure 4
Relationship between land area and the volume of lending



*Note: The variable is the difference between the county's share of lending (A: amount of loans disbursed in the county / national volume of lending) and its geographical importance (B: land area of the county / land area of the country), multiplied by 100. Index = (A–B)*100. There are more than 3,000 counties. Gray indicates a lack of data.*

Source: HMDA

Figure 5
Relationship between land area and population



*Note: The variable is the difference between the proportion of inhabitants in the county (A: population of the county / population of the country) and its geographical importance (B: land area of the county / land area of the country), multiplied by 100. Index = (A–B)*100. There are more than 3,000 counties.*

Source: HMDA

On average, in lending, the weight of counties exposed to heat days exceeds that of less exposed counties (*Table 3*, examining variable E above). However, the difference is statistically significant largely only for heat variable 2 – the increase in the number of heat days. This is primarily due to the high level of lending activity in the south-eastern part of the country, particularly in several counties in Florida, where a significant increase in the number of heat days is expected. By contrast, some areas that are already hot (and will be among the hottest in 30 years), such as several counties in Arizona, have relatively low lending activity. *Table 3* shows, for example, that counties where the number of heat days is forecast to rise by at least 50 have an average difference of 0.042 percentage points between their share of lending and their share of land; in other counties it is approximately 0 (Test 5). The difference is not insignificant in economic terms either, since the average share of a county in both lending and land area is 0.03 percentage points (1/3,067 *100) in the 3,067 counties in our study, and such a difference between the counties' shares of lending and land area is not typical (in absolute value, the difference is less than 0.04 percentage points in 79 per cent of the counties and less than 0.03 percentage points in 69 per cent of the counties).

The spatial distribution of loan applications (*Figure 2 and 3*) is very similar to that of loans (*Figure 2 and 3*): thus, in the areas most exposed to climate change, proportionally more loans are applied for than the proportion of land area would justify, but not more than the economic activity and the population of the areas would explain. In other words, the expectation of how much a given area will change in the future in terms of livability does not seem to play a significant role in lending activity, either on the supply or on the demand side. In any case, a more formal analysis of the behaviour of lenders is conducted in the following.

Table 3
Importance of lending broken down by heat days

Number of heat days in 30 years					
Test	**Group**	**Observations**	**Average**	**St. error**	**Prob (T<t)**
1. >=130	0	2,871	–0.001	0.003	
	1	196	0.014	0.013	
	Diff (0–1)	3,067	**–0.015**	0.013	0.135
2. >=140	0	2,982	–0.001	0.003	
	1	85	0.037	0.028	
	Diff (0–1)	3,067	**–0.038***	0.028	0.088
3. >=150	0	3,015	–0.000	0.003	
	1	52	0.015	0.039	
	Diff (0–1)	3,067	**–0.015**	0.039	0.348
Increase in the number of heat days					
Test	**Group**	**Observations**	**Average**	**St. error**	**Prob (T<t)**
4. >=45 days	0	2,868	–0.001	0.003	
	1	199	0.012	0.006	
	Diff (0–1)	3,067	**–0.012****	0.006	0.032
5. >=50 days	0	2,989	–0.001	0.003	
	1	78	0.042	0.014	
	Diff (0–1)	3,067	**–0.043*****	0.014	0.002
6. >=55 days	0	3,034	–0.001	0.003	
	1	33	0.082	0.028	
	Diff (0–1)	3,067	**–0.083*****	0.028	0.003

*Note: 2-sample t-test assuming different standard deviations. The examined variable is the difference between the role of the county in lending (A: volume of loans disbursed in the county / volume of loans disbursed in the country) and its geographical importance (B: geographical extent of the county / geographical extent of the country), multiplied by 100. Variable = (A–B)*100. Group 1 indicates the counties exposed to extreme heat based on the number of future heat days (cut-off values for Tests 1, 2 and 3: 130, 140 and 150 heat days, respectively), or based on the expected increase in the number of heat days (cut-off values for Tests 4, 5 and 6: +45, +50 and +55 heat days, respectively). Prob (T<t) indicates the significance level at which we can reject the null hypothesis that the mean value is the same in the two groups and accept the alternative hypothesis that the mean value of group 1 is greater than that of group 0. Statistically significant differences are marked also with asterisks: * significant at 10%, ** significant at 5%, *** significant at 1%.*

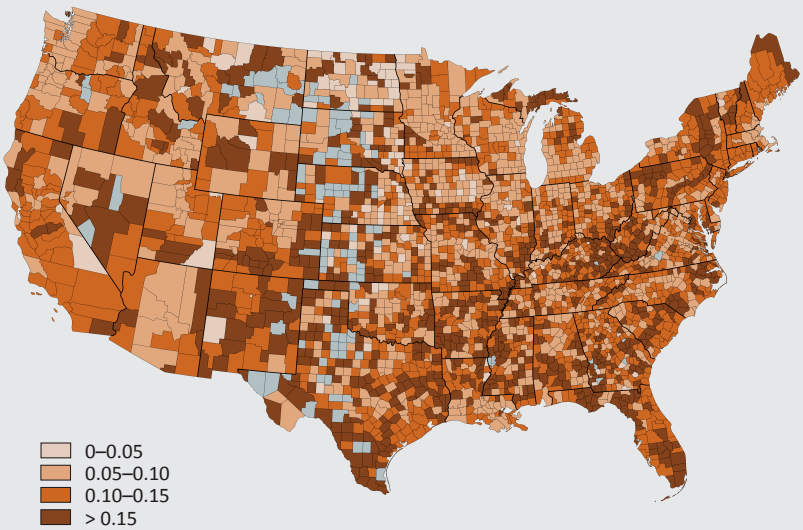
Source: ACIS, HMDA

4.2. Simple denials rate

We examine whether the relatively high volume of lending flowing to the counties most exposed to heat waves may be driven by lower denials by lenders, or the logic is that banks have a reduced preference for these areas because of future risks, but demand pressures still result in significant lending. We first look at this based

on the simple denials rates. In many places, the rate values in the northern-central part of the country are low (or absent); these are areas less exposed to future heat (*Figure 6*). Many southern counties (Florida, Texas, some counties in New Mexico) have higher denials rates.

Figure 6
Simple denials rate

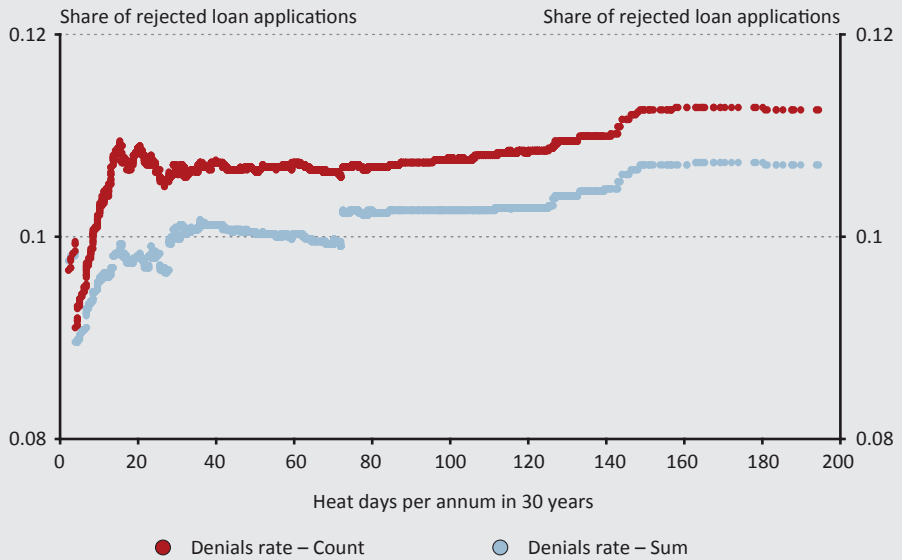


Note: The simple denials rate is the ratio of denied loan applications to the sum of disbursed loans and denied loan applications. No rate is calculated for fewer than 10 loan contracts (grey area).

Source: HMDA 2019, mapchart.net

In this context, we find that lenders' willingness to lend is slightly lower in places most exposed to climate change. More loan applications are denied in areas where, for example, more than 150 days of heat are expected in 30 years (*Figure 7*). *Figure 8* shows that in areas where the number of heat days is expected to increase only minimally, fewer loan applications are denied than in counties more exposed to climate change. In the northern counties in general, somewhat fewer loan applications are denied, which is reflected, among other things, in the low values of the X-axis in *Figures 7 and 8*. And at the high values of the heat variables, the southern counties with the highest denials rate and the highest exposure to heat appear in the cumulative denials rate. There may be reasons independent of climate change behind the pattern, but it is also possible that the future macroeconomic expectations used in the lender's decisions reflect climate change to some extent. *Figures 7* and *8* use lending data for 2019; in general, though not exclusively, a similar pattern characterises the various years in the past decade.

Figure 7
Cumulative denials rate as a function of the expected number of heat days in the area in 30 years



Note: The figure shows the proportion of loan applications that were denied by the lenders, based on the number of loan applications or the amount of loan applied for. For a given x, we calculate with the population of loan applications where at the location of the real estate (county) x or fewer heat days (>90°F) are expected in 30 years (average of 2041–2050). The figure reflects a total of more than 5 million loan applications, and the cumulative denials rates are shown from a minimum population of 50,000 loan applications. Lending data: 2019.

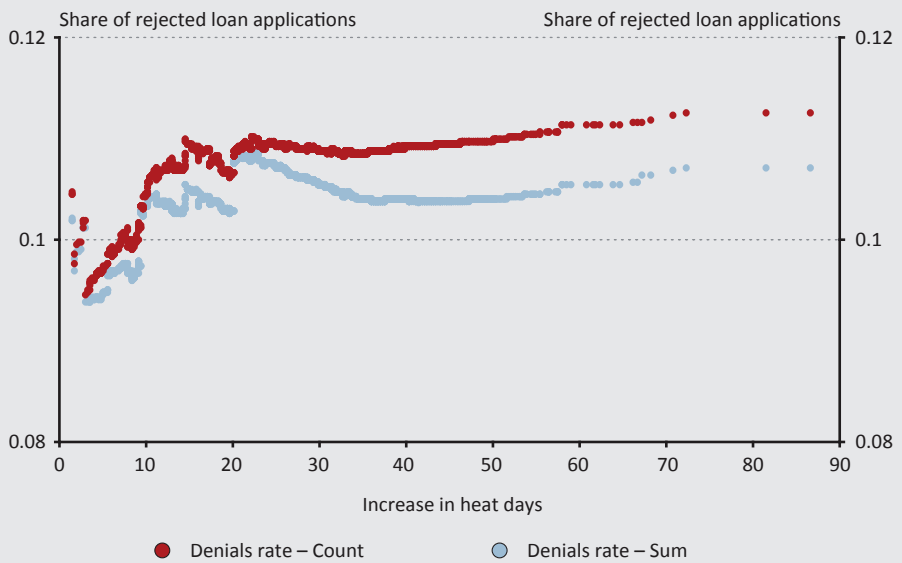
Source: ACIS, HMDA

4.3. Sophisticated denials index

The loan denial pattern in *Figure 7* and *8* does not necessarily reflect the willingness of lenders to lend, as there may be regional differences in the characteristics of loan applications. It is possible, for example, that in some areas loan applications have a higher risk and therefore there is a higher rate of denials, with unchanged willingness to lend. Spatial differences in the risk of loan applications may be the result of climate change-related or non-climate change-related causes. An example of the former is when wealthy people with good credit ratings move away from areas most vulnerable to climate change.

In the sophisticated denials index, we try to filter out the available loan application parameters, such as the demographic characteristics of the borrower or the size of the loan relative to income. Thus, using equation (1), we construct a county-level index and then examine the spatial distribution of the index values.

Figure 8
Cumulative denials rate as a function of the expected warming of the area



Note: The figure shows the proportion of loan applications that were denied by the lenders, based on the number of loan applications or the amount of loan applied for. For a given x, we calculate with the population of loan applications where at the location of the real estate (county) the increase in the number of heat days (> 90°F) is x or fewer over the next 30 years (average of 2041–2050 minus the most recent historical data: the average of 2003–2012). The figure reflects a total of more than 5 million loan applications, and the cumulative denials rates are shown from a minimum population of 50,000 loan applications. Lending data: 2019.

Source: ACIS, HMDA

Statistical tests continue to show that, on average, slightly more loan applications are denied in the counties most exposed to temperature change (looking at both future levels and changes) (*Table 4*). In areas where at least 150 heat days are expected in 30 years, the average value of the index is 0.23, which is 5 percentage points higher than the average for the rest of the country (*Table 4*, Test 3), and in the areas where the projected increase in the number of heat days is at least 50 days, the average value of the sophisticated denials index of 0.2 is 0.02 higher than the average of areas where heat waves are less expected to increase (*Table 4*, Test 5). Applying different cut-off values for the extreme level and change, there is a statistically significant difference between the average index values of the extreme and less exposed areas in all cases examined (*Table 4*, tests 1–6). It can be considered significant also in an economic sense if out of every 100 dollars of loan applications 2 to 5 dollars more are denied in the areas that are most exposed to future heat.

Table 4
Sophisticated denials index based on climate exposure

Number of heat days in 30 years					
Test	**Group**	**Observations**	**Average**	**St. error**	**Prob (T<t)**
1. >=130	0	8,621	0.178	0.001	
	1	576	0.210	0.004	
	Diff (0–1)	9,197	**–0.032*** **	0.004	0.000
2. >=140	0	8,945	0.179	0.001	
	1	252	0.223	0.006	
	Diff (0–1)	9,197	**–0.044*** **	0.006	0.000
3. >=150	0	9,043	0.179	0.001	
	1	154	0.232	0.009	
	Diff (0–1)	9,197	**–0.053*** **	0.009	0.000
Increase in the number of heat days					
Test	**Group**	**Observations**	**Average**	**St. error**	**Prob (T<t)**
4. >=45 days	0	8,610	0.179	0.001	
	1	587	0.197	0.003	
	Diff (0–1)	9,197	**–0.019*** **	0.003	0.000
5. >=50 days	0	8,966	0.179	0.001	
	1	231	0.203	0.004	
	Diff (0–1)	9,197	**–0.024*** **	0.004	0.000
6. >=55 days	0	9,098	0.180	0.001	
	1	99	0.201	0.005	
	Diff (0–1)	9,197	**–0.022*** **	0.005	0.000

*Note: 2-sample t-test assuming different standard deviations. The examined variable is the sophisticated denials index. Group 1 indicates the counties exposed to extreme heat based on the number of future heat days (Tests 1, 2 and 3: from 130, 140 and 150 heat days, respectively) or based on the expected increase in the number of heat days (Tests 4, 5 and 6: from +45, +50 and +55 heat days, respectively). Prob (T<t) indicates the significance level at which we can reject the null hypothesis that the mean value is the same in the two groups and accept the alternative hypothesis that the mean value of group 1 is greater than that of group 0. Statistically significant differences are also marked with an asterisk: significant at *** 1 per cent.*

Source: ACIS, HMDA

5. Central bank options

In the introduction and literature review, we described the economic and financial stability risks that climate change may pose, and from this perspective, we then examined the spatial pattern of the mortgage market activity in the US. Our results show that the areas highly exposed to climate risk experience significant lending outflows, even if their denials rates are relatively slightly higher. These facts

underline the need for central banks, as state actors regulating and supervising the financial system, to address the impact of climate change on the financial system as a priority. In the following, we discuss potential climate change objectives, central bank actions and their context, using the above US mortgage lending example. The possible directions discussed here go beyond the dilemmas of just one dimension (heat waves) or one country (the US), but illustrate the problem that essentially all banking systems are facing or will face in the coming years.

In this chapter, we review, in a non-exhaustive manner, some possible objectives and related central bank[6] measures at different points on the path to mitigating heat wave risks. Some objectives and related measures are less controversial and closely in line with the traditional responsibilities of central banks (*Brunnermeier – Landau 2020*). Examples include the measurement, disclosure and incorporation of climate risk into the capital and liquidity requirements of financial system actors. Others, however, would proactively contribute to the cause of environmental sustainability in the fight against climate change. Legitimacy concerns of the latter measures can be reduced by a clear political mandate. There are already examples where the mandate of the central bank includes the promotion of environmental sustainability as a secondary objective (*MNB 2021a*).

In order to effectively promote environmental sustainability, optimally, there is coordination between the country's public authorities – central government, local authorities, central bank, etc. In this way, multiple incentives can push in the same direction, towards well-defined climate targets. The aim may be, for example, to improve public authorities' understanding of future exposure to heat waves or to build buildings in areas of extreme exposure appropriate from an environmental sustainability / climate exposure perspective.

Recognising the importance of climate risks, in the context of the Network for Greening the Financial System (NGFS), formal efforts are also made by central banks and supervisory authorities to share best practices and formulate recommendations to manage climate risks and promote the financing of sustainable economy (*NGFS 2021*). The NGFS – of which the Federal Reserve Board has been a full member since the end of 2020 (*Brainard 2020*) – has made the following recommendations to central banks (*MNB 2021a:16*)*:*

- Expand the range and improve the quality of data;
- Integrate sustainability considerations into the central bank's own portfolio management;

[6] It varies from country to country whether the central bank responsible for monetary policy and the authority(ies) responsible for the regulation and supervision of financial institutions operate under the umbrella of the same institution. In the following part of this paper, the term central bank is used to cover both functions.

- Consider climate risks in financial stability monitoring and the supervision of institutions;
- Promote green financial awareness;
- Support the harmonisation of climate-related disclosures; and
- Support the development of international taxonomy.

In the following, we look at possible central bank measures that also fit the NGFS recommendations for arbitrarily chosen targets, but specifically related to exposure to heat waves (*Table 5*).

Table 5
Objectives and measures related to heat waves

	Possible objective	Possible central bank measure
1	Detailed information on the risk of heat waves	Supervisory data collection on the exposure of mortgage loans to heat waves
2	Market transparency regarding the exposure of financial actors to heat waves	Supervisory requirement to extend financial reporting
3	Understanding the risk of heat waves	Integrating the effects of heat waves into stress tests
4	Managing financial actors' risks related to heat waves	Amendment of the framework for capital and liquidity requirements for credit institutions
5	Build appropriate buildings in areas most exposed to heat waves	Changes to collateral policy, asset purchase programmes, changes to capital and liquidity requirements for credit institutions
6	Reduce construction rates as much as possible in areas most exposed to heat waves	
7	Reduce population in places most exposed to heat waves	Lending ban, collateral policy, capital and liquidity requirements

More information (*Objectives 1 and 2*)

Improving data coverage is a first and essential part of risk mapping, and is included in the NGFS recommendations. This can be done by combining climate projection data with data from financial actors, as used in this study, or by increasing data provision to supervisory authorities. In the former, we see that even the coverage of publicly available US mortgage data, which is internationally unparalleled in its detail, is not perfect. In addition, if the aim is to publish data, spatial resolution is also a key issue, since for certain risks, such as sea level rise, it is important to know the exact location, which may be subject to personal data protection restrictions.

Although the Financial Stability Board's Task Force on Climate-Related Financial Disclosures (TFCD) has been calling for progress on climate-related financial reporting for several years (*TFCD 2017*), implementation will take years and is not

uniform across countries (*TFCD 2021*). Among the NGFS recommendations, we find that central banks are pushing for the development of standardised disclosures. Following from the example examined in the first part of our study, lenders could share in a uniform manner the proportion of loans disbursed in locations most exposed to extreme heat, as well as the environmental sustainability and resilience characteristics of the real estate used as collateral.

Understanding and managing the climate risks of financial actors (*Objectives 3 and 4*)

A growing number of central banks are exploring the possibility of incorporating climate change risks into bank stress tests in order to gain a deeper understanding of the implications for financial stability. Bank stress testing is a framework in which various shocks can be simulated over different time horizons to provide a complex examination of how specific scenarios might affect a credit institution (*Boros 2020*). Such a shock could be for example the withdrawal of a major agricultural company from the area due to heat waves, which could affect economic output, demographics and housing prices in the area.

Stress tests are suitable for assessing the impact of climate change precisely because of their forward-looking nature and their ability to deal with uncertainty around climate change through scenarios involving different assumptions. The first half of our study, for example, uses averages of temperature projections from international climate models, which are also available in UN publications and on the Climate Explorer website created for the US public. But the stress test can also be run based on climate models predicting more extreme heat waves. For example, as part of its green programme, the MNB is also using a long-term climate stress test to examine loan repayment rates under different scenarios (*MNB 2021b*). The largest banks emphasise this very feature of climate stress testing: they can perform sensitivity tests on the climate exposure of their assets (*UNEPFI 2018*).

Climate stress tests, while seemingly promising as a method to quantify risks, face a number of challenges (*Boros 2020*). These are partly due to the difficulties of quantifying the economic and financial aspects of physical-ecological knowledge. One major challenge is to capture long-term stress tests and the knock-on effects and feedbacks as fully as possible, as stress tests have so far mainly focused on a 2–3 year period. The field is relatively new and is attracting considerable attention in the financial world. When developing climate stress tests for heat waves, it is worth paying particular attention to the time horizon, as long-term negative socio-economic impacts can be incorporated into real estate market variables even in the short term (*Baranyai – Banai 2021*). A market consensus is forming regarding the local economic and demographic changes caused by future heat waves, regulatory actions and the behaviour of lenders; and in the long term, the knock-on effects

and repercussions (in multiple circles) of the behaviour of the actors involved must also be taken into account.

Once risks have been stress-tested and quantified through other methods, it would be appropriate to integrate the climate dimension into the financial supervision framework (*Brunnermeier – Landau 2020*). In our case, for example, to ensure that an adequate capital and liquidity buffer is available to the financial actors that are exposed to heat waves.

Promote environmental sustainability (*Objectives 5–7*)

For the issue under study, the aim could be to encourage building in an environmentally sustainable way, especially in areas exposed to heat waves (*Objective 5*). A more radical objective could be to avoid an increase (*Objective 6*) or even achieve a decrease (*Objective 7*) in social and economic presence in the areas most exposed to heat waves.

The central bank can support environmental sustainability objectives with both prudential policy and monetary policy instruments (*Brunnermeier – Landau 2020*). A prudential policy tool is the discount applied to capital requirements that can be provided for certain activities considered sustainable (*Akbari et al. 2015*), such as financing buildings using sustainable cooling technologies (*Lundgren – Kownacki et al. 2018*). Such measures are controversial, as they can separate the riskiness of the activity from the appropriate level of capital, and the definition of sustainability is not clear. A monetary policy measure would be to narrow the range of eligible collateral and to tailor collateral values and asset purchase programmes according to environmental sustainability criteria. An example of this is when mortgages on real estate in areas exposed to extreme heat waves are excluded from the range of collateral accepted by the central bank.

A fundamental question is whether the central bank should reward environmentally sustainable activity or punish activity that goes against it. The MNB's green bond purchase programme is an example of a rewarding approach (*MNB 2021a*). The Swedish Riksbank's practice of only buying corporate bonds that are considered sustainable is an example of the latter.

Our analysis suggests that credit demand may be the main reason behind the higher disbursement of credit to the counties most exposed to heat waves relative to their share of territory. Supervisory measures, on the other hand, mainly affect the credit supply side. A simple lending freeze imposed on credit institutions may have many unintended side effects. If the supply of credit falls more steeply than demand, various less supervised shadow banking system players may step in to meet the demand for credit. The supervisory authority and the central bank should therefore act with particular caution and in cooperation with other authorities.

6. Summary

Climate scientists predict that our climate will change significantly in the coming decades, even if humanity takes rapid and effective steps to transition to a low-carbon economy. One aspect of this is that the number of heat days will increase in many areas.

High temperatures have well documented negative effects on the human body, productivity and the economy. And the most effective protection against heat available today – air conditioning – is environmentally unsustainable. It is, therefore, important where and with what technology the buildings and neighbourhoods that will face tomorrow's climate are built today.

Through the financing of buildings, via mortgage lending, the participants in the financial world also have an impact on the ecological footprint of human activities, and are themselves exposed to climate change. For both reasons, therefore, it is advisable to look to the future and take climate change into account in financing decisions.

In this study, we used the example of US mortgage lending to examine whether more mortgages are originated in counties most vulnerable to future heat waves, relative to their land area, economic importance and population. Our conclusion is that there are slightly more mortgages in these areas compared to their land share, and this is mainly due to larger economic and population presence. Lenders deny slightly more loan applications in these areas, providing further evidence that it is not a higher lending appetite that is behind the higher lending volumes in heat-prone areas. Similar analyses for other countries or climate change dimensions can enrich our knowledge on the relationship between mortgage lending and climate change.

Central banks are also increasingly recognising that climate change can have a fundamental impact on the goals set out in the central bank mandate. Quantifying the risk is a necessary first step, which can be supported by data collection and stress testing. As part of its green programme, the MNB is also using a long-term climate stress test to examine loan repayment rates under different scenarios. Stress tests can be used to capture the knock-on effects and feedbacks for different scenarios, as for example the incorporation of climate risks into the real estate market may trigger reactions from the local population, the economic and financial sectors as well as local policy makers. It is then appropriate to incorporate the risks into supervisory procedures. Central banks can support the transition to environmental sustainability through their collateral policies and asset purchases. The central bank can opt to use positive incentives, but it can also adopt a punitive approach. In order to promote environmental sustainability, it is beneficial if different public authorities

take coordinated action around commonly agreed goals. In areas where existing housing will not be or will be less sustainable from an environmental point of view, central bank measures could support the use of appropriate architectural solutions or even reduce lending. Our example of mortgage lending in the US and central bank goals to promote environmental sustainability show that climate targets can have a major impact on the (regional) economy and society. It is therefore also important to address the legitimacy of the measures.

Hungary is among the warming countries as well: the number of hot days in the summer is projected to increase until 2100, and maximum temperatures are also expected to rise. For example, the average temperature in August will be 1.5–8°C higher under different scenarios.[7] Although climate scientists suggest that there will be regional differences in the increase in the frequency of heat waves within the country, Hungary's smaller size means that these will not be as significant as in the US. Issues related to the spatial distribution of lending in preparation for climate change are thus likely to be less of a focus than in the US. However, because of the interactions between the microclimate and the buildings, this does not mean that it is unnecessary to consider the advantages and disadvantages of a spatially differentiated approach. The phenomenon of urban heat islands, for example, is well documented in the literature and can be mitigated by certain construction techniques. And the properties of the financed buildings can be influenced by the central bank, as the MNB does this with the green loan.

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[7] The interval represents the median values of the five scenarios (SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0, SSP5-8.5).

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Banking Sector Exposures to Climate Risks – Overview of Transition Risks in the Hungarian Corporate Loan Portfolio*

Renátó Ritter

Risks arising from climate change can have a serious impact on the operation of the financial system. In this study, the credit exposures of banks and bank branches operating in Hungary are assessed using two methodologies. To put the results of the analysis into context, they are compared with the results of the survey conducted by the European Banking Authority using the same methodologies. Based on both methodologies, Hungarian institutions may be exposed to the negative effects of climate change at a higher rate than their counterparts in the European Union. Using the two methods together, risk groups were formed, on the basis of which 1.2 per cent of Hungarian institutions were classified in the upper quartile and more than 55 per cent of the banking system was classified in the upper-middle quartile. The methods presented can help not only assess the banking system's transition exposures at the systemic level, they can also be used to assess corporate credit exposures at the institutional level.

Journal of Economic Literature (JEL) codes: C81, G21, Q54

Keywords: climate change, transition risk, sectoral exposure, greenhouse gas intensity

1. Introduction

Climate change is certain to have an impact on countries' economic performance. As some of the most important economic players, banks deserve special attention, and their financing activities have a serious indirect impact on the state of the environment. In particular, institutions may be exposed to two types of risk arising from climate change: transition risks and physical risks (*PRA 2015*).[1]

* The papers in this issue contain the views of the authors which are not necessarily the same as the official views of the Magyar Nemzeti Bank.

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[1] As a third type of risk, the Prudential Regulation Authority (PRA) in the UK highlighted liability risk for insurers.

Transition risks are risks that threaten market actors during the transition to a carbon-neutral economic structure. The Task Force on Climate-related Financial Disclosures (TCFD) of the Financial Stability Board assigns transition risks to the following four main categories: (i) policy and legal risks, such as the negative economic effects resulting from more stringent policy measures due to climate change (e.g. carbon taxation, phasing-out of carbon-based energy production); (ii) technology risks, which include shocks resulting from technological shifts (e.g. phasing-out of cars equipped with combustion engines); (iii) market risks, which can be understood as negative effects due to changes in preferences (e.g. investors excluding brown assets from their portfolios or consumers shifting preference to sustainably-produced goods); (iv) reputational risks, i.e. a negative shift in the perception of a given economic operator and the resulting economic disadvantage (e.g. share price declines due to an operator's behaviour and its perception) (*TCFD 2020*). Physical risks are subdivided into two types by the TCFD: (i) acute weather events (e.g. floods, forest fires) and (ii) chronic risks (sea levels, temperature rise). Authorities supervising financial institutions increasingly focus on quantifying the effects of climate change on the stability of the economy. The motivation of the study was to assess the extent of the transition risks accumulated in the balance sheets of Hungarian credit institutions in such a manner that the results would be comparable with the surveys of other authorities, in particular the European Banking Authority (EBA). Consequently, for the purposes of this analysis, internationally applied methodologies are used.

The study is structured as follows: *Section 2* assesses the transition exposures of the Hungarian banking system based on the Climate Policy Relevant Sectors (CPRS) approach (*Battiston et al. 2017*). In *Section 3*, based on the EBA methodology, Hungarian corporate credit exposures are classified into greenhouse gas (GHG) intensity groups at the debtor level (*EBA 2021*). In *Section 4*, the results of the two methodologies are compared and the relevant policy steps and proposals that have emerged to date are presented, and in *Section 5*, the conclusions are discussed along with an outline of the implications for improvements.

2. Assessment of transition risks using the CPRS approach

2.1. Data set used

In my analysis, I used stock data for the end of 2021 Q2 and relied on credit data from reporting under Magyar Nemzeti Bank (the central bank of Hungary, MNB) Decree No. 35/2018. (XI. 13.)[2] (HITREG). In the analysis, I included all credit institutions, branches of credit institutions and specialised credit institutions operating in Hungary, whereby exposures were analysed for the credit portfolio of a total of 32 institutions. The analysis is limited to credit exposures to non-financial corporations incorporated in Hungary and non-profit institutions serving households. The exposure amounts were generated on the basis of the principal balance field in HITREG. The principal balance of the overall corporate credit exposure amounted to HUF 9,492 billion, i.e. 96 per cent of the corporate loan portfolio registered by the MNB. The difference may be explained by the exclusion of self-employed entities from the analysis. The EBA conducted its own survey based on the exposures of 29 European banks at the end of 2019, which included only loans to large companies operating in Europe. In its analysis, the EBA used the total original exposure values from the COREP[3] reports, which amounted to EUR 2.35 trillion, representing 42 per cent of loans to companies operating in the European Union (EU)[4] (*EBA 2021*). Due to the difference between the portfolios covered by the EBA and this analysis, and to the analytical considerations described below, the results are not exactly compatible with each other, but they provide a good reference point for putting the Hungarian situation into context.

2.2. The CPRS approach

In their 2017 study, *Battiston et al.* set out the approach for potential CPRS to quantify the exposures potentially affected by climate change. Since then, the approach has been adopted by a number of supervisors and financial institutions. The approach can be widely used since it does not require additional information, but is based entirely on the statistical classification standard for economic activities introduced by the EU (*Eurostat 2008*), which combines the general EU classification code for a given economic activity, NACE Rev. 2.[5] Consistent use of NACE Rev. 2 codes provides comparable information to compare the levels of exposure to individual industries across EU countries. In the rest of the study, the term section is used collectively to refer to the corresponding sections (A–T) and divisions (A01–T98).

[2] A Magyar Nemzeti Bank elnökének 35/2018. (XI. 13.) MNB rendelete a jegybanki információs rendszerhez a hitelügyletek egyes adataira vonatkozóan teljesítendő adatszolgáltatási kötelezettségről (Decree No 35/2018. (XI. 13.) MNB decree by the Governor *the Magyar Nemzeti Bank on reporting obligations for the central bank information system in relation to certain credit data*). https://www.mnb.hu/statisztika/informaciok-adatszolgaltatoknak/rendeletek-allasfoglalasok/35-2018-xi-13-mnb-rendelet

[3] The EBA Common Reporting Framework

[4] COREP (Common Reporting Requirements) 07.00.a and 08.01.a.

[5] Nomenclature générale des activités économiques dans les Communautés Européennes

The CPRS approach assumes that sections of the economy whose activities involve higher GHG emissions will be more affected by regulatory action to mitigate climate change than their counterparts with lower emissions. Based on Eurostat data, the sectors with the largest direct (scope 1 CO_2 equivalent) GHG emissions are identified as a first step, mainly in the sections of utilities, transport, agriculture, manufacturing and households. Furthermore, the CPRS approach specifically names mining, whose direct emissions in scope 1 are relatively low, but, as a supplier to the sections listed above, plays an important role either directly or indirectly (*Battiston et al. 2017*). The classification system also takes into account the classification of so-called carbon leakage risk, which identifies activities (mainly in the manufacturing industry), the competitiveness or costs of which may be strongly affected by carbon control measures, such as the introduction of a carbon tax (*EC 2014*). It is clear that the traditional NACE Rev. 2 classification standard is difficult to use from a climate policy perspective, due to the inadequately homogeneous allocation of activities in terms of climate regulation. For example, in the section of mining and quarrying, there are activities which are expected to be subject to less serious policy action than their counterparts in the same section (e.g. iron ore mining will be less climate policy relevant than hard coal mining registered in the same section), while in manufacturing there are activities (e.g. petroleum refining) which will be highly climate policy relevant in comparison with other activities (*Battiston et al. 2017*). Attention must also be paid to the fact that specifically green activities are not categorised separately in the standard system, such as renewable solar power plants operating in the energy supply sector as coal power plants.

All of the economic activities considered fall into three categories: (i) fossil fuel supplier, (ii) electricity supplier, and (iii) fossil fuel user or electricity user. The third group can be further divided into the traditional policy areas of transport, accommodation and manufacturing. While the supply side of fossil fuels will be most affected by regulatory action to reduce GHG emissions, it can also have a positive and negative impact on other categories, depending on the energy source (fossil or renewable energy). Based on the above, all economic activities can be categorised into *climate policy relevant sectors* or other sectors based on the classification of NACE Rev. 2 level 4.[6] Under the approach, corporate exposures are classified into the following sectors: (1) fossil fuel, (2) utilities, (3) energy intensive, (4) housing, (5) transport, (6) agriculture, (7) finance, (8) scientific research and development, and (9) other. Of these, sectors 1 to 6 are deemed to be involve increased exposure to transition risk and are collectively referred to CPRS 1–6 exposures in the remainder of the study. Under the approach, sectors marked 7 to 9 do not carry transition risks.

[6] https://www.finexus.uzh.ch/en/projects/CPRS.html

Based on the above, the strength of the approach is that it is based on generally available data (NACE Rev. 2 classification), the exposures can be fully assessed (all sectors pertaining to economic activities), and the bank exposures are classified into manageable categories, so that easily understandable results are obtained. The disadvantage of the approach is that it inaccurately assesses companies operating multiple businesses in different sections, since the NACE Rev. 2 classification reflects only the main activity of the company, and the main activity is often incorrectly defined, or the classification simply becomes obsolete and fails to follow the changes in the life of the company. Another disadvantage is that rather than quantifying the risks arising from climate change, the approach merely identifies the exposures concentrated in each sector. As I mentioned earlier, the approach may misclassify activities into groups that are highly exposed to transition risks, even though the activity in question may support the green transition. One example is renewable energy production in the energy supply sector, which is a large GHG-emitting sector in general.

2.3. CPRS exposures in the Hungarian banking system

When analysing the corporate loan portfolio of the domestic banking system, it is useful to first examine the level of exposures to industries before turning to the exposure values reflected in the CPRS approach. When looking at the distribution of sectoral exposures, *Table 1* shows that there are areas in which the banking system has a significant credit exposure, such as manufacturing, real estate, trade and vehicle repair, in which 61 per cent of corporate credit exposures are concentrated.

Table 1
Exposure values and distribution by sector

Sections	Exposure value (HUF billions)	Distribution of exposure (%)
A – Agriculture, forestry, fishing (agriculture)	457.20	4.82
B – Mining and quarrying	8.08	0.09
C – Manufacturing	2,198.48	23.16
D – Electricity, gas, steam and air conditioning supply (energy supply)	327.49	3.45
E – Water supply; sewerage, waste management and remediation activities (water and waste management)	41.41	0.44
F – Construction	570.93	6.02
G – Wholesale and retail trade; repair of motor vehicles and motorcycles	1,648.45	17.37
H – Transportation and storage	563.10	5.93
I – Accommodation and food service activities	315.25	3.32
J – Information and communication	208.05	2.19
K – Financial and insurance activities	17.72	0.19
L – Real estate activities	1,971.50	20.77
M – Professional, scientific and technical activities	730.59	7.70
N – Administrative and support service activities	294.90	3.11
O – Public administration and defence, compulsory social security	0.20	0.00
P – Education	12.62	0.13
Q – Human health and social work activities	55.18	0.58
R – Arts, entertainment and recreation	35.80	0.38
S – Other service activities	34.86	0.37

Source: MNB

The analysis only includes the credit exposures of domestic companies that are assigned to a NACE Rev. 2 classified, so that the CPRS exposure values can be generated for the entire corporate loan portfolio analysed. The database does not include traditional small-scale producers and self-employed entities, which are registered as retail loans, and the analysis also did not include the transaction risks in loans to foreign companies.

After completing the CPRS classification of domestic credit exposures, almost 61 per cent of the exposures of the banking system were classified as highly exposed to transition risks, which is higher overall than the results of the survey conducted by *EBA* (*2021*). The EBA analysis identified 58 per cent of the bank credit exposures to large companies operating in Europe as CPRS 1–6 exposures. In Hungary, the

CPRS 1–6 exposures are mainly accounted for by real estate activities (34 per cent) and manufacturing (23 per cent), as opposed to the EBA survey, in which real estate activities are less strongly represented in the CPRS 1–6 exposures (22 per cent). The EBA results do not specifically identify the CPRS 1–6 share of agriculture (it is included in other categories); however, in Hungary it carries more weight in proportion to these loans, and thus I considered it appropriate to include it in the list (*Table 2*).

Table 2
Distribution of CPRS 1–6 exposures across national economy sectors

Section	Distribution of exposures in Hungary (%)	Distribution of exposures in the European Union (%)
A – Agriculture	8	N/A
C – Manufacturing	23	34
D – Energy supply	6	13
F – Construction	8	10
H – Transportation and storage	9	9
L – Real estate activities	34	22
Other	13	12

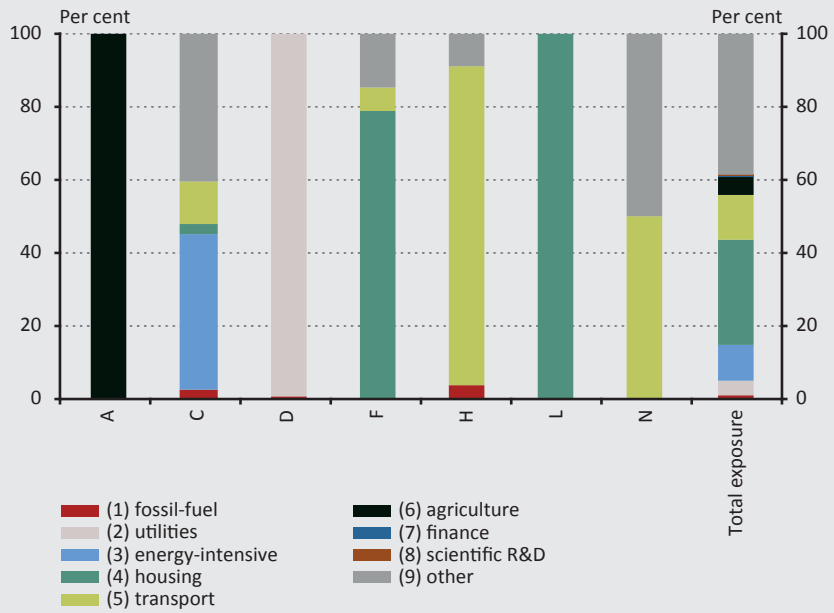
Source: MNB, EBA (2021)

Based on the CPRSs that can be identified in each section, we can obtain information on which specific sectoral regulations may have a stronger impact on the performance of companies operating in that section. From *Figure 1*, it is apparent that some sections are considered completely homogeneous based on the classification of climate policy relevant sectors, i.e. in the event of more stringent policy measures, some sections may become more risky in their entirety. Not surprisingly, agriculture as a whole was identified as the agricultural sector under the approach, the situation being similar in the case of real estate activities – housing sector. A good example of more stringent policy measures is the emergence of new agricultural regulations, the greening of the EU's Common Agricultural Policy,[7] the transition efforts of which (perceived by many as insufficient) can reduce the profitability of the entire group of companies engaged in agricultural activity and indirectly increase the value-at-risk in the loans granted here.

[7] Frost, R. (2021): *CAP: What is the EU's Common Agricultural Policy and why is it trending?* Euronews, 26 November. https://www.euronews.com/green/2021/11/26/cap-what-is-the-eu-s-common-agricultural-policy-and-why-is-it-trending. Downloaded: 8 February 2022.

Not altogether surprisingly, manufacturing is found to be the most heterogeneous section, with the widest variations in the activities of individual companies. Due to the high presence of the 'other' category, this section is not so severely affected by increasingly stringent policy measures in specific CPRSs; therefore, under the CPRS approach a significant part of the manufacturing industry (40 per cent) is not climate policy relevant. While the value for the administrative and support service activities section may be surprising, it also includes machinery rental and leasing activities, which may be affected by transition risks.

Figure 1
Distribution of sections with the highest CPRS 1–6 exposures by CPRS



Note: The figure only covers sections with high CPRS 1–6 exposures. For less exposed sections, exposures were predominantly identified as other sectors. A – Agriculture, forestry, fishing; C – Manufacturing; D – Electricity, gas, steam and air conditioning supply; F – Construction; H – Transportation and storage; L – Real estate activities; N – Administrative and support service activities.

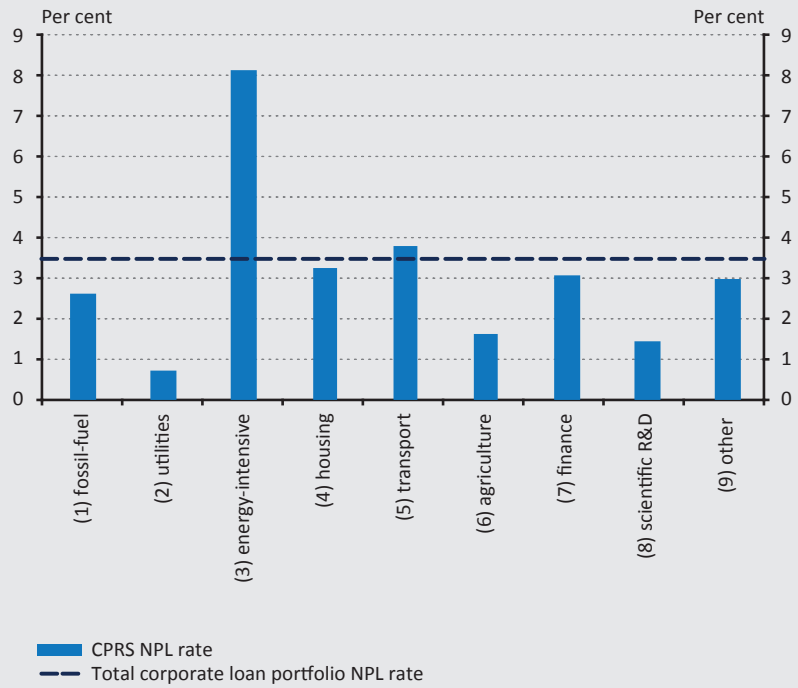
Source: MNB

It is also worth mentioning the different NPL ratios of each CPRS. The ratio of non-performing loans to total credit exposure (NPL ratio), as defined in Articles 5 and 6 of MNB Decree 39/2016,[8] varies by CPRS, which may indicate the resistance of each sector to regulatory shocks. Sectors with already higher-than-average NPL ratios are likely to exhibit a less favourable response to more stringent policy measures (*Figure 2*).

[8] https://net.jogtar.hu/jogszabaly?docid=a1600039.mnb

The average NPL ratio of the total corporate credit exposure is 3.49 per cent, with higher NPL ratios in the energy-intensive and transport sectors (respectively 8.20 and 3.79 per cent). These exposures account for 22 per cent of the total corporate credit exposure. Almost 61 per cent of non-performing exposures were identified as CPRS 1–6 exposures, similar to the EBA's results (60 per cent).

Figure 2
NPL variations across CPRSs



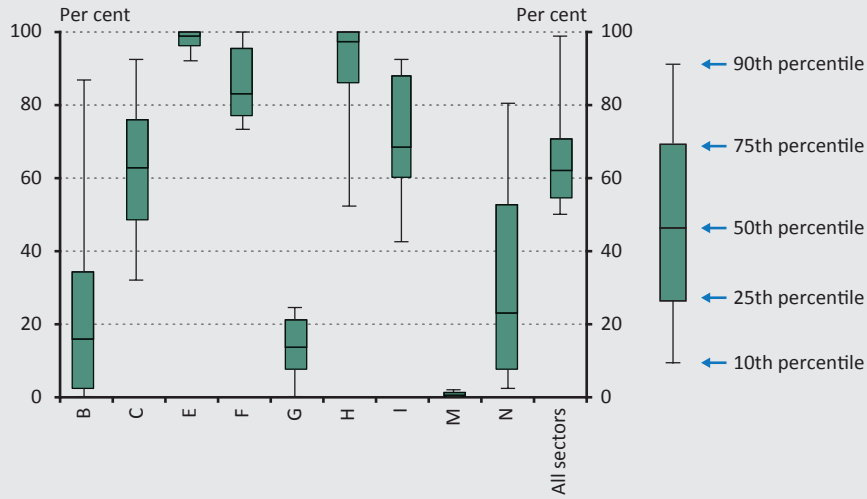
Source: MNB

As mentioned earlier, sections of the national economy show varying levels of relevance to climate policy. In order to quantify this, the CPRS exposure of each bank within the section was examined in relation to its total exposure to the section. *Figure 3* shows the distribution of credit institutions' CPRS ratios by section, which can be interpreted as the exposures of each institution to sections being classified as CPRS 1–6 or CPRS 'other', so that the section value of each institution varies between 0 and 100 per cent, where 100 per cent means that the total exposure to the section qualifies as CPRS 1–6 exposure. *Section 3* shows the section values

of the institutions, i.e. how individual institutions' CPRS 1–6 and CPRS 'other' exposures are distributed in each sector. One-quarter of the data falls below the 25th percentile, and three-quarters above. The 75th percentile halves the upper part of the data, with three-quarters of the data below it, and one-quarter of the data above. The 50th percentile is the median for the data. In the figures, only the values between the 10th and 90th percentiles are indicated, in order to eliminate the outliers, and small banking portfolios were omitted from the analysis (section exposures below HUF 100 million), which would also distort the meaning of the figure by showing accumulated risks even where the exposures at hand are not significant. *Figure 4* and *5* below are also to be interpreted as above.

Several institutions have accumulated significant CPRS exposures in certain sections. For one-half of the banks, more than 60 per cent of exposures to manufacturing, water and waste management, construction, transportation and storage, and accommodation and food service sections qualify as CPRS exposures (*Figure 3*). This means that potentially upwards of 60 per cent of the section portfolio of specific banks could be affected by more stringent policy measures in the section, which would affect the creditworthiness of their debtors operating in the section. The most important indicator in this respect is the proportion of CPRS exposures in each banking portfolio across all sections. For one-half of the banks, more than 62 per cent of their exposures were identified as CPRS exposures, while 10 per cent of the institutions had nearly all of their exposures (99 per cent) financing climate policy relevant sectors. This is mainly due to the exposures of small institutions, mortgage banks to the section of real estate activities. In the EBA survey, EU institutions had a higher CPRS concentration per section, with one-half of the banks having more than 70 per cent of their exposure financing CPRS exposures in the manufacturing, water and waste management, construction and transportation and storage sections. Both surveys identified 100 per cent of exposures to agriculture and energy, and nearly 100 per cent of exposures to real estate activities as CPRS exposures.

Figure 3
Banks' CPRS exposures by national economy section

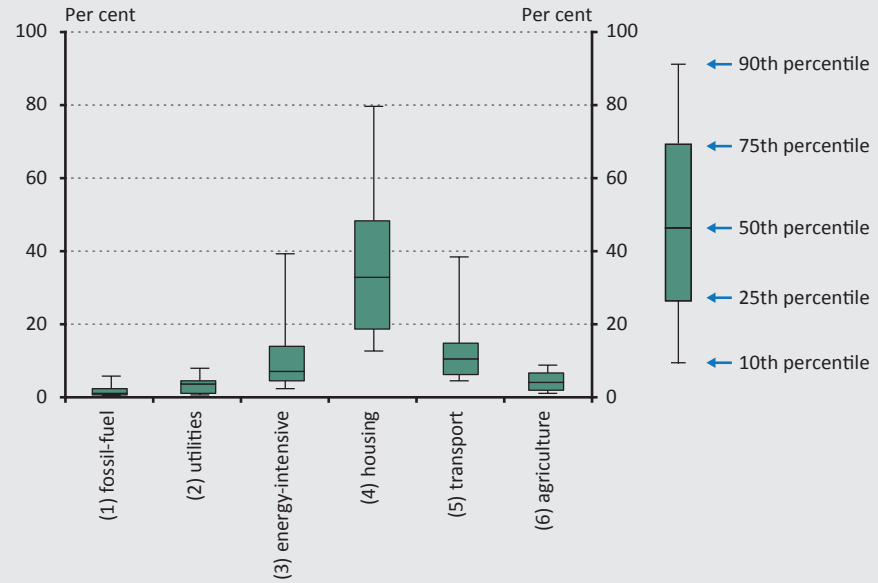


Note: B – Mining and quarrying; C – Manufacturing; E – Water supply; sewerage, waste management and remediation activities; F – Construction; G – Wholesale and retail trade; repair of motor vehicles and motorcycles; H – Transportation and storage; I – Accommodation and food service activities; M – Professional, scientific and technical activities; N – Administrative and support service activities.

Source: MNB

At some banks, a major proportion of the exposures are concentrated in specific climate policy relevant sectors (*Figure 4*). The percentage of the total corporate portfolios of individual institutions that is used to finance specific CPRSs was also examined. The highest concentration of bank exposures was found in the housing sector, where one-half of the institutions report more than 32 per cent of the exposures financing the sectors; but this is also where the largest outliers are found. One small institution is fully exposed to the housing sector, which may pose a serious risk to its stability. There are lower concentrations in other sectors, but the median value of the energy-intensive and transport sectors (7 and 10 per cent, respectively) is still noteworthy.

Figure 4
Bank exposures to CPRSs



Source: MNB

3. Assessment of banks' GHG risk based on the EBA's methodology

While no uniform methodology for measuring the carbon risks to banks' portfolios has been adopted so far, several calculation methods have already been defined to quantify these risks. One common feature in those methods is the use of GHG intensity, which shows the amount of GHG emissions associated with one euro of added value. European Union countries' intensity data are compiled by Eurostat comprehensively for sections (NACE Rev. 2 Level 1: A-T) and not comprehensively for divisions (NACE Rev. 2 Level 2: A01–T98) (*Bokor 2021*). As the data are updated with a lag of two to three years, the most recently available actual data on intensity from 2018 were used in the analysis, disregarding the estimated values for 2019. The methodology of the MNB's Banking Carbon Risk Index (hereinafter BCRI) published in 2021 (*Bokor 2021*) is also based on this database, which assesses the carbon risk of bank portfolios with two functions, based on the GHG intensity of each economic activity. The two functions capture different interpretations of the risks arising from GHG intensity. As mentioned previously, TCFD (*TCFD 2017a*) defined several indicators to measure the carbon exposure of banking, insurance, fund

management, investment service and fund portfolios, focusing on the weighted average carbon intensity indicator[9] (*TCFD 2017b:43*).

In its analysis, the EBA takes a simpler approach to the quantification of risks arising from the GHG intensity of portfolios compared to the above-mentioned methods: using the available intensity data, it classifies banking exposures into six groups of GHGs: (i) very low, (ii) low, (iii) medium, (iv) medium/high, (v) high and (vi) very high. Corporate exposures are matched on the basis of NACE Rev. 2 Level 2 with their respective GHG exposure values and then assigned to the appropriate group on the basis of criteria derived from GHG intensities (*Table 3*). The EBA also used individual enterprise GHG emissions data (17 per cent of the corporate exposures had individual values) for the purpose of its analysis, resulting in more nuanced group thresholds, as opposed to using only section-level intensity data. For the preparation of this study, no individual company emissions data were available, and thus the grouping was based solely on section-level GHG intensity data. Almost all of the corporate loan portfolios considered for the analysis included available section-level GHG intensity data.

Table 3
Classification of GHG intensity groups and corporate exposures

GHG group	Entry criterion	Exposure amount (HUF billions)	Distribution (%)
Very low	GHG ≤ P10	2,047.23	21.6
Low	P10 < GHG ≤ Q1	1,100.26	11.6
Medium	Q1 < GHG ≤ Median	1,256.91	13.2
Medium/High	Median < GHG ≤ Q3	3,432.86	36.2
High	Q3 < GHG ≤ P90	1,227.90	12.9
Very high	GHG > P90	426.44	4.5

Note: P10 – 10th percentile, Q1 – 1st quartile (25th percentile), Q3 – 3rd quartile (75th percentile), P90 – 90th percentile.
Source: MNB

In Hungary, more than 53 per cent of corporate exposures are used to finance activities above the median GHG intensity, which is significantly higher than the 35 per cent figure obtained by the EBA. The difference can be explained partly by the difference in the GHG intensity data used for grouping (individual vs. section-level). However, it is not surprising that, overall, Hungarian banks show a higher ratio of financing GHG-intensive sectors than their counterparts in the European Union. Although it decreased by 45 per cent between 1995 and 2019 due to the transformation of the country's economic structure and industrial sector, the energy intensity of Hungary's economy (energy consumption per unit of economic output)

[9] Weighted average of Carbon Intensity, WACI

is still almost twice as high as the EU average (*MNB 2021a*). Nevertheless, based on GHG intensity, almost one-half of corporate exposures may be affected, to varying degrees, by transition risks such as the record-high carbon allowance price of EUR 60 at the end of the summer.[10]

Based on the results of the BCRI referred to above, in 2021 Q2 the ratio of the corporate loan portfolio financing exposures considered to be extremely high risk in terms of GHG intensity (*Bokor 2021*) was 8 per cent using a linear function and 15 per cent on the basis of a Gompertz sigmoid function. The index assumes a functional relationship between risks and GHG intensity: thus, the higher the GHG intensity of a given activity, the higher the risk value assigned under the method. In contrast to the linear function, the Gompertz function hardly penalises less GHG-intensive activities, while exposures that are considered to be too polluting at a certain point are fully included in the risk category. The Gompertz result thus obtained corresponds approximately to the amount of credit covered by the high and very high GHG group that I identified. The EBA and the GHG grouping methodology used here classify the respective exposures into GHG intensity groups on the basis of critical values (see the inclusion criterion), and therefore the results are not fully compatible with the results of the BCRI's methodology based on a functional relationship, but both methods yield a similar picture.

In the analysis, I identified several major pollutant national economy sections. 77 per cent of the very high category was accounted for by energy supply, while the remaining part was accounted for by manufacturing (16 per cent) and water and waste management (7 per cent). More than 27 per cent of the high category was made up of manufacturing, while 37 per cent was made up of the agricultural sectors, but high ratios were also found in transportation and storage (20 per cent) and, surprisingly, in administrative and support service activities (15 per cent). The latter belongs in the high category at such a high rate because this section includes the machinery rental and leasing services divisions, which are considered to be activities with a high GHG intensity.

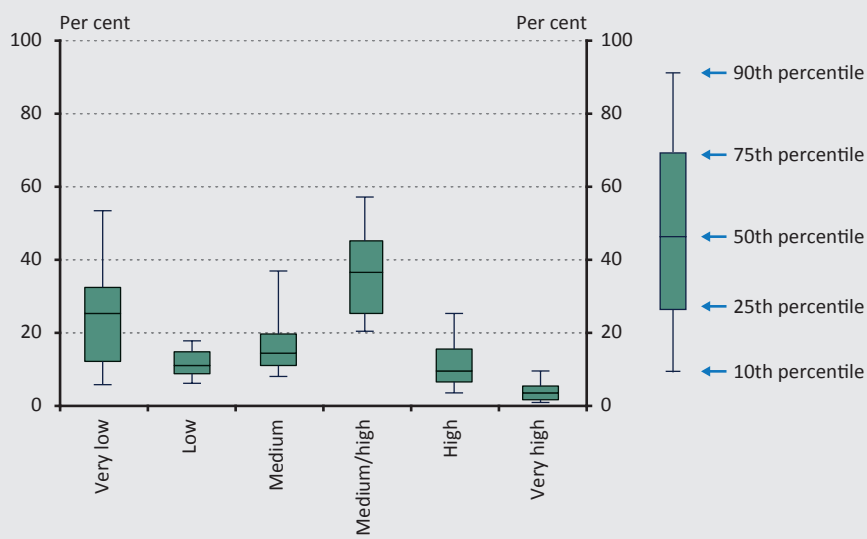
The results are supported by Hungary's GHG emission data. Based on the most recent revised data from the HCSO from 2018, 72 per cent of greenhouse gas emissions came from economic activities.[11] The most polluting energy supply sector accounted for 19 per cent of total emissions. The GHG emissions of the manufacturing industry were strongly affected by the degradation of heavy industry, the modernisation of the chemical industry and the decline in fuel consumption due to the financial crisis in 2009 (*HCSO 2017*). Nevertheless, the second most

[10] Hook, L. (2021): *Carbon price rises above €60 to set new record*. Financial Times, 30 August. https://www.ft.com/content/c1a78427-f3d5-4b4f-9878-c3e1dffee2ba. Downloaded: 22 November 2021.
[11] Annual GHG emissions data are published by the HCSO for Hungary in the form described here. https://www.ksh.hu/stadat_files/kor/hu/kor0018.html. Downloaded: 15 February 2022.

polluting section of the national economy is responsible for about 16 per cent of total emissions in 2018, followed by agriculture at 12 per cent. In terms of GHG emissions, the real estate activities section is strikingly absent, the activity of which is associated with relatively low GHG intensity based on both Eurostat and HCSO data (according to HCSO data, the sector accounted for less than 1 per cent of total emissions in 2018), whereas in practice real estate indirectly accounts for a significant proportion of GHG emissions, as 28 per cent of 2018 GHG emissions can be attributed to households (who obtain homes through real estate), primarily related to heating and car use (the latter not related to real estates).

In the following, I assessed how the exposures of the individual banking portfolios are distributed across GHG intensity groups. Although the proportion of GHG exposures is higher than in the EBA survey, in terms of GHG concentration, the portfolios of Hungarian credit institutions are arguably more diversified than those of their counterparts in the European Union (*Figure 5*). In the EBA survey, half of the banks financed activities with very high GHG intensity with more than 10 per cent of their exposure, while the median value of Hungarian institutions in the same group was only slightly more than 3 per cent. However, it is important to mention the outliers: 10 per cent of Hungarian institutions finance such activities with more than 9 per cent of their exposures, while the most polluting institution has 54 per cent of its exposures in highly polluting activities.

Figure 5
Distribution of bank portfolios across GHG groups



Source: MNB

The median value of the high category exceeds 9 per cent, i.e. the portfolio of one-half of the institutions finances activities with high GHG intensity to an extent exceeding 9 per cent, which is approximately the same as in the EBA results. Institutions with outliers can also be found in the high category, with one institution financing such activities at 41 per cent and another at 34 per cent.

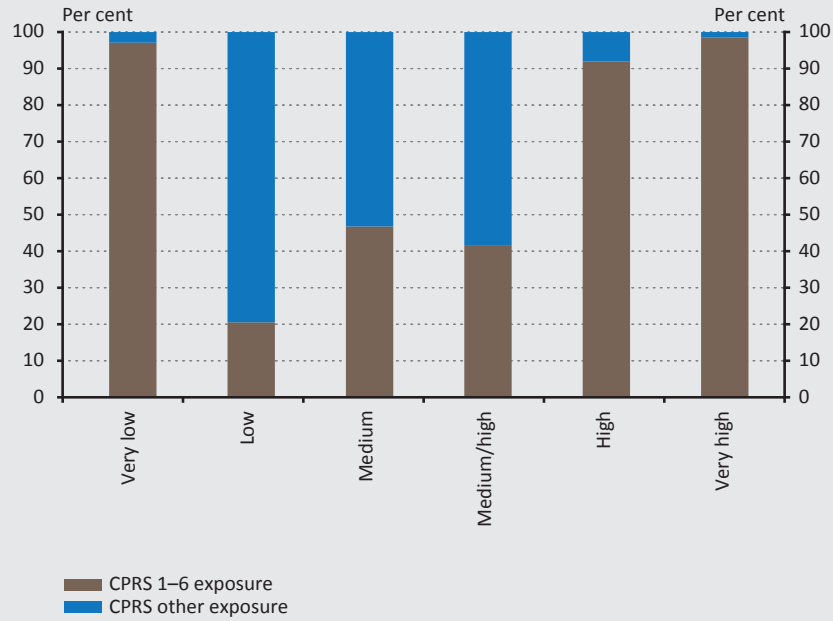
There are large variations in the other GHG intensity groups. The exposures of the Hungarian banking system above the median GHG intensity are concentrated primarily in the medium/high category, and the median value of the category (37 per cent) significantly exceeds the results of the EBA (nearly 20 per cent). It is also important to mention the very low GHG intensity group. As explained earlier, the intensity data for real estate activities are misleadingly low, while the value of bank exposure for these activities is significant (21 per cent of the total corporate exposure), which largely explains the high share of the very low group.

4. Comparison of banks' GHG and CPRS exposures

4.1. Overlaps between the two methodologies

Either of the two methodologies presented so far can, in itself, provide an insight into the exposure of a portfolio to transition risks, but it is worth using the two together in order to avoid ignoring risky activities that are successfully identified by only one of the methods. As we have seen, both methods are capable of assessing highly polluting activities (*Figure 6*), with 98 per cent of the very high GHG group and 92 per cent of the high GHG group identified through the CPRS approach. The agreement is also due to the fact that by design the CPRS approach relies heavily on the data of the average GHG intensity of each economic activity, as mentioned in the description of the approach. The accuracy rate is lower in the medium and medium/high groups, with 47 and 42 per cent of these activities identified as CPRS, respectively. We can see contradictory results for the very low categories, which is mainly attributable to the real estate activities mentioned earlier; although the CPRS approach classifies this section as climate relevant, Eurostat attributes it to a very low GHG intensity. The difference can be explained by the methodology used by Eurostat for the production of GHG data, i.e. the resulting GHG emissions are taken into account where they are actually released into the atmosphere, so that real estate activities have no direct responsibility, but a large degree of indirect responsibility for the emissions that may occur in energy supply (for example, the emissions arising from the heating and electricity supply of homes). Thus it can be concluded that transition risks cannot be fully assessed on the basis of a single methodology: relying solely on GHG data would have resulted in ignoring the transition risk exposure of a very significant section.

Figure 6
Relationship between GHG and CPRS classification



Source: MNB

It is important to reiterate that in its assessment the EBA used specific GHG emissions data, where the CPRS approach followed the GHG groups created based on individual emissions data much more closely. The EBA also identified CPRS exposures in the very low category (nearly 15 per cent), but the option cannot be ruled out that a given company, although classified with an activity exposed to climate change according to its NACE Rev. 2 code, carries out its activity more sustainably and with less emissions than its competitors. It is therefore possible that corporate credit exposures considered to be exposed to transition risks based on their activities may also occur in the lower GHG intensity categories if the individual emissions of the given companies are lower than the section average.

4.2. Identified transition risk groups

In view of the foregoing, it is advisable to start using the results of both methodologies to determine the transition climate risk of an institution. I determined the risk exposure of an institution by placing them in a figure where the X-axis shows the ratio of the bank's exposure value to its total corporate exposure as assessed under the CPRS approach, and the Y-axis shows the share of exposures above the median GHG intensity in the total corporate exposure (*Figure 7*). The resulting risk grid is divided into four blocks, with credit institutions classified

into the following categories: (i) upper quartile, (ii) upper-middle quartile, (iii) lower-middle quartile and (iv) lower quartile (*Table 4*). In the upper quartile, I classified the institutions where at least 75 per cent of each portfolio finances activities exposed to climate change on the basis of both GHG intensity and the CPRS approach; 1.2 per cent of the Hungarian banking system belongs here in terms of balance sheet total. In the next group, I classified institutions where at least 50 per cent of each portfolio finances activities exposed to transition risks under both methodologies; such institutions make up a major part of the Hungarian banking system, with over one-half (55 per cent) of the institutions belonging in this category.

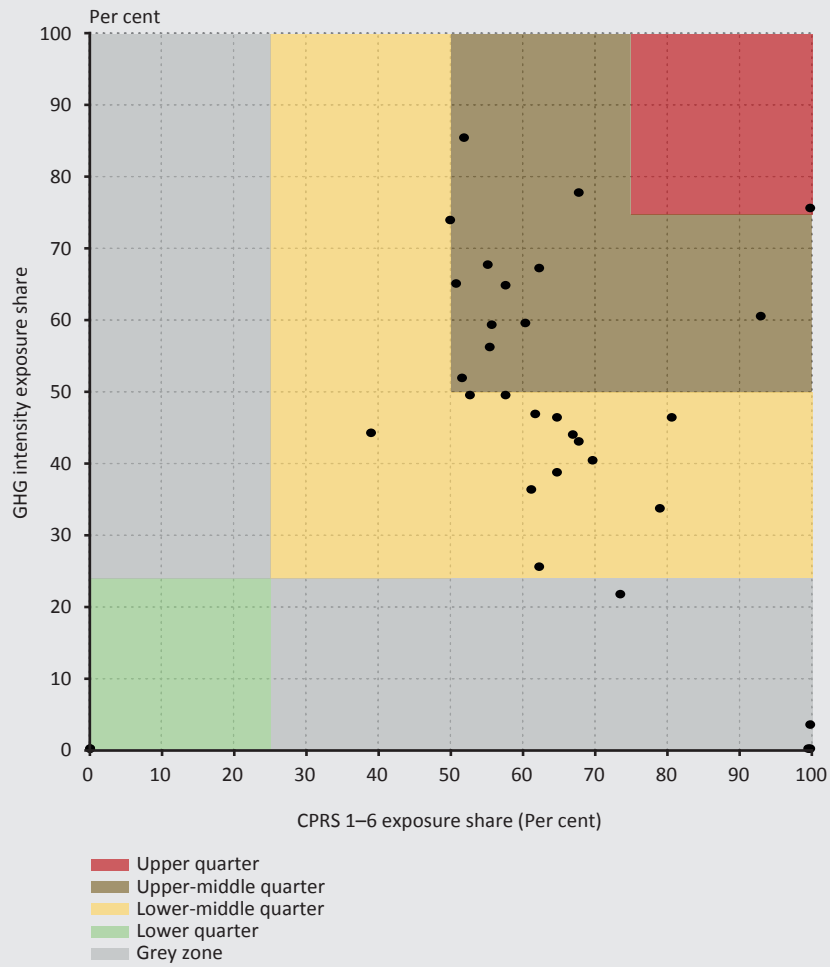
Table 4
Transition risk groups identified in the Hungarian banking system

Group	Threshold	Distribution of the banking system (by corporate credit exposure, %)	Distribution of the banking system (by balance sheet total, %)
Upper quartile	CPRS 1–6 exposures and GHG exposures above the median >= 75%	0.00	1.20
Upper-middle quartile	CPRS 1–6 exposures and GHG exposures above the median >= 50%	49.00	55.10
Lower-middle quartile	CPRS 1–6 exposures and GHG exposures above the median >= 25%	50.30	39.70
Lower quartile	CPRS 1–6 exposures and GHG exposures above the median < 25%	0.00	1.30
Grey zone	At least one of CPRS 1–6 exposures and GHG exposures above the median > 25%	0.60	2.70

Source: MNB

I construed the grey zone as comprising the two cases where only one of the two methodologies will capture transition risk. In this category, it may be appropriate to carry out further studies on the portfolios of the relevant institutions; for example, in this group, it would be really important to carry out the survey on the basis of individual GHG data. This may be relevant to 2.7 per cent of the Hungarian banking system. Finally, I identified a group with low climate risk exposures, whose exposures finance less than 25 per cent of activities exposed to transition risks based on both methodologies, which is 1.3 per cent of the Hungarian banking system.

Figure 7
Climate risk grid of the Hungarian banking system



Source: MNB

4.3. Policy actions to date and their outcome

In the light of the results, it is not surprising that the MNB has launched a corporate and municipal capital requirement reduction programme from 2021 onwards in order to mitigate climate risk in the institutions' portfolios (*MNB 2020*). The programme, which was expanded in the summer of 2021 (*MNB 2021b*), covers not only renewable energy production as announced initially, but also green corporate credit exposures related to electromobility, sustainable agriculture and the food industry, as well as energy efficiency. In assessing the sustainability of exposures, the

MNB relied on the documents established by the EU defining sustainable economic activities, the EU Taxonomy Regulation[12] and its technical annex published to date.[13]

Over the course of six months, 1 per cent of the total corporate loan portfolio was included in the scheme, but this had a significant impact on the operation of two branches of the economy, which were traditionally classified as the largest polluters, as 26 per cent of the credit exposures to Section D – Energy and 21 per cent of the exposures to Section B – Mining and quarrying were included. If the green loans submitted as part of the MNB's green capital requirement reduction scheme are taken into account when determining the risk exposures, the CPRS 1–6 of the total corporate credit exposure decreases from 61 per cent to 60 per cent as described above. The combination of the ratio of green loans and the reduction in CPRS confirms that the scheme has well defined the range of transactions to be supported.

With the expansion of the scheme, the greening of other economic sections can be expected at a similar pace. In addition to the introduction of incentives, the MNB also seeks to draw the attention of credit institutions to the importance of the risks arising from climate change as quickly as possible. In the first half of 2021, the MNB issued a Green Recommendation to the sector, in which it "*sets expectations regarding the management of climate change and environmental risks, as well as the enforcement of environmental sustainability aspects in the business activities of banks*" (*MNB 2021c*).

4.4. Proposal for credit institutions

The methodology outlined earlier may not only be suitable for assessing the risk of the corporate loan portfolio of the entire banking system, but may also be used for assessing the transition risks inherent in corporate loans at the institutional level. The institution can use the two methods to assess which of its debtors are identified as risky under the CPRS approach based on the GHG intensity and which debtors are identified as risky under both methodologies (or neither). The advantage of the method is that it is a simpler, easy-to-implement method of analysis compared to the tools available so far, complete with a table of correspondence[14] for CPRS classification (*Battiston et al. 2017*), and annually updated Eurostat GHG intensity data,[15] which – in the absence of individual emissions data – can be used to calculate GHG groups.

[12] *Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088*. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32020R0852&from=EN. Downloaded: 15 November 2021.

[13] *Commission Delegated Regulation (EU) 2021/2139 of 4 June 2021 supplementing Regulation (EU) 2020/852 of the European Parliament and of the Council by establishing the technical screening criteria for determining the conditions under which an economic activity qualifies as contributing substantially to climate change mitigation or climate change adaptation and for determining whether that economic activity causes no significant harm to any of the other environmental objectives*. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32021R2139&from=EN#d1e622-1-1. Downloaded: 15 November 2021.

[14] https://www.finexus.uzh.ch/en/projects/CPRS.html

[15] https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_ac_aeint_r2&lang=en

Institutions may also have additional information on the activities of their debtors, such as whether they are operating in multiple sectors or have a corporate climate adaptation strategy, thus clarifying the results of the baseline classification.

4.5. Implications for improvements

The analysis can be improved from a number of perspectives. By expanding the range of exposures, we can obtain a more accurate picture of the accumulated climate exposures in institutions, for example by analysing the exposures arising from securities, in particular corporate bonds, bank-book shares and shares purchased in investment funds. The analysis did not include debt in loans registered as retail exposures to self-employed entities and traditional small-scale producers,[16] who are important for the subject, nor the potential transition risks in foreign corporate exposures, so it may be justified to examine all of these more closely at a later stage. As I noted previously in several instances, the setup of GHG intensity groups on the basis of individual emissions data and judgement of debtors on the basis of their individual emissions data would greatly contribute to the accuracy of the analysis. When determining the risk exposures, more attention could be paid to the green loans submitted as part of the MNB's green capital requirement reduction scheme. While under the CPRS approach manual reclassification is viable (the aggregate effect of which is described above), in the case of GHG intensity groups, in the absence of individual emissions data, it is not clear which group the known green transactions should be classified into. As regards the analysis as a whole, I have largely relied on the NACE Rev. 2 classification, which is the main activity of the companies and which, as mentioned above, can often mislead the analysis. The accuracy of the analysis would be greatly enhanced if the actual principal activity of the companies were recorded separately in HITREG, and would also be greatly clarified if the activities financed by each loan were identified. The distribution of the revenue data of individual companies according to NACE Rev. 2 would also greatly clarify the results if the database of the National Tax and Customs Administration of Hungary included these data.

The classification results of exposures may provide good input data for the stress testing of institutions, as already used in CPRS classifications by *Battiston et al.* (*2017*) and *Roncoroni et al.* (*2021*). A steadily growing number of central bank climate stress test exercises (*Vermeulen et al. 2018*; *Muñoz et al. 2021*; *MNB 2021d*) have sought to quantify the financial risks arising from climate change, which may be relevant for a more accurate grasp of the various diversions of exposures identified on the basis of the methodologies presented above in the context of different scenarios and assumptions.

[16] With both small-scale producers and self-employed entities, the problem was that they were registered as retail loans rather than corporate loans, whereby including this data set would have made it very difficult to carry out the analysis.

5. Summary

At the beginning of the study, I laid down the conceptual framework, defining the risks arising from climate change and then presented the data set used in the analysis. The analysis was based on data from 2021 Q2, covering corporate credit exposure totalling HUF 9,492 billion. After presenting the theoretical background to the CPRS approach, I assessed the Hungarian corporate exposures of credit institutions operating in Hungary, first examining the exposure of individual sections to transition risks and then the extent of transition risks built up in individual banks, and compared the results with the results of the research carried out by the EBA. According to the analysis, 61 per cent of the exposures examined were classified as highly exposed to transition risks, which is overall higher than the 58 per cent measured by the EBA, but there was a higher concentration in the institutional portfolios, and half of the institutions financed activities exposed to transition risks to a greater extent than 62 per cent. According to the results measured on the basis of the GHG intensity methodology, the institutions operating in Hungary financed activities above the median GHG intensity to a greater extent than their counterparts in the European Union, and compared to the 35 per cent measured by the EBA, nearly 54 per cent of corporate exposures in Hungary are financing such activities. However, contrary to the results of the CPRS approach, it can be stated that no clearly large polluting institutions can be identified in Hungary compared to the European Union banks surveyed by the EBA, and the exposures to the transition risks associated with GHG intensity are relatively evenly distributed throughout the banking system.

When the results of the two methodologies are examined together, 5 groups can be defined based on the exposure of the respective institutional portfolios to transition risks. 1.2 per cent of the Hungarian banking system belongs in the upper quartile group, which carries high transition risks under both methodologies, and more than one-half (55 per cent) of the Hungarian banking system belongs to the upper-middle quartile group, involving the second highest level of exposure. A significant part of the banking system falls into the lower-middle quartile, with nearly 40 per cent of the institutions belonging here. Only slightly more than 1 per cent of the institutions belong in the lower quartile, representing the lowest levels of exposure to transition risks. I identified nearly 3 per cent of the institutions as belonging in the grey zone, where more granular data may be required for establishing a more accurate standpoint. Finally, I presented the regulatory steps taken by the MNB on the subject so far, highlighting the results of the green corporate and municipal capital requirements discount, which are also relevant for the study, i.e. the emergence of green corporate loans in traditionally large polluting sections. I have also drawn up an easy-to-implement, low-cost methodology for the institutions to comprehensively assess their transition risks. A future research objective may

be the implementation of the improvements discussed at the end of the study, which would provide a more accurate picture of the risks inherent in the Hungarian banking system. The more accurate the picture we have of the climate risks built up in banks' balance sheets, the easier it is to tackle the economic challenges of climate change at both the regulatory and institutional levels.

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Credit Risk Modelling of Mortgage Loans in the Supervisory Stress Test of the Magyar Nemzeti Bank*

András Viktor Szabó

The study aims to develop a model that can estimate potential credit risk losses for housing and home equity loans using both macro and micro data, can be applied uniformly to all banks and takes into account the new accounting standards (IFRS 9). The model is based on a deal-level database for several Hungarian credit institutions, covering an entire business cycle (2004–2018). It uses economic indicators that strengthen risk sensitivity while also including transaction characteristics that mitigate procyclicality. Modelling in a two-step process allows risk groups to be created during forecasting in accordance with various credit characteristics. The results show that the evolution of employment has a stronger effect on riskier groups which potentially have only ad-hoc employment, while net wealth was not even among the explanatory variables for the group containing the best debtors, who presumably rely more on stable earned income.

Journal of Economic Literature (JEL) codes: C320, C530, G210, G280, G510

Keywords: time series modelling, econometric forecasting, bank, stress test, PD, household credit, IFRS 9

1. Introduction and literature review

Stress testing and the corresponding credit risk models gained increasing prominence in the wake of the 2008 global economic crisis. This is attested by the introduction of stress tests by international banking supervision bodies as well as the supervisory function of the *Magyar Nemzeti Bank* (the central bank of Hungary, MNB) since 2017. This study seeks to develop a model that can be applied

* The papers in this issue contain the views of the authors which are not necessarily the same as the official views of the Magyar Nemzeti Bank.

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uniformly to all banks, takes into account the new accounting standards (IFRS 9), and can estimate potential credit risk losses for housing and home equity loans to households using both macro and micro data. The model is based on a transaction-level database for several Hungarian credit institutions, covering an entire business cycle (2004–2018), and uses economic indicators that strengthen risk sensitivity while also allowing deal characteristics that mitigate procyclicality to be included in the modelling. One of its main unique aspects is that modelling is conducted in a two-step process, which allows different macroeconomic variables to exert a varying impact on risk groups created according to different credit characteristics, i.e. debtors in heterogeneous situations and risk buckets. The results confirm this theory because, for example, the evolution of employment has a stronger effect on the riskier groups who potentially have only ad-hoc jobs, while net wealth was not even among the explanatory variables of the group containing the best debtors, who presumably rely more on stable earned income.

Experts at credit institutions and regulatory authorities realised the risks these institutions face to due to their lending activity decades ago. Towards the end of the 20th century, as quantitative methodologies were being developed, portfolio-level modelling of credit risk became increasingly popular, leading to a wealth of studies and referenced models. Among reduced credit risk models, which estimate the parameters of a default through an exogenous jump process rather than through the change in market capitalisation (*Bielecki – Rutkowski 2004*), the literature differentiates between two types. The first comprises intensity models, concerned with the time of default, while the second one, which is more interesting for the purposes of this work, includes models based on credit migration. Since the 1990s, most models focused on estimating three parameters: the probability of default (PD), loss given default (LGD) and the correlation between PD and losses (*Crouhy et al. 2000*). *Das et al.* (*2009*) observed that the models estimating PD based on the concept of default as understood by Merton[1] started to be crowded out by reduced-form models in the early 2000s, as they could include any number of explanatory variables, even client-specific or macroeconomic variables, which further improved the accuracy of the estimate. Of course, this came at the same time as the publication of the Basel II accords in 2004, which underscored the need for banks' internal credit risk assessment, thereby encouraging earlier methods to be renewed and made more precise.

[1] In Merton's approach, a highly stylised model yields the probability of default, and the only explanatory variable is the value of the company's assets.

The idea of credit rating modelling is attributed to *Altman* (*1968*), who used accounting characteristics in his study[2] in an attempt to estimate the PD of various firms. This train of thought was continued and fine-tuned by several others over the following years, for example, by *Martin* (*1977*), *Platt – Platt* (*1991*) and *Sommerville – Taffler* (*1995*), to name but a few. *Lawrence et al.* (*1992*) did not model companies' probability of default; instead they approached the problem from the side of household lending, which makes it partly similar to the methodology used in the present study. The main objection to credit scoring models is that their explanatory variables are pieces of static, accounting information that are unable to immediately capture sudden changes, as they do so only with a delay (*Agarwal – Taffler 2008*). Having recognised this, credit risk experts increasingly turned towards factor models in the early 2000s. These models aimed at information compression usually use two vectors for the estimation. The first typically includes mostly accounting information that deals with rapid effects too rigidly, but captures client quality characteristics well, while the second vector complements it by mainly including macroeconomic indicators supporting dynamism. If it can be considered unchanged over time, the first (e.g. type of loan repayment, time to maturity, educational attainment of the client at the time of application) is mostly used for exploring and quantifying individual risks, while the latter can capture external, systemic risks. Many authors have published articles describing factor or multi-factor models. Among these, *Pederzoli and Torricelli* (*2005*) deserves special mention, in which the authors described the contradictory relationship between risk sensitivity and procyclicality in connection with the Basel II capital requirement calculation, and proposed to mitigate it with a hybrid PD model using both risk group-based (rating) method and a TTC (through-the-cycle) approach. The present study also presents a modelling practice using two types of vectors or set of variables.

The 2008 global economic crisis opened up the eyes of financial market participants to the fact that the modelling methods used until then were unable to provide an accurate picture of the banking sector's credit exposure and fell short in qualitative or quantitative terms in terms of their approach. The unanimous wish of the stakeholders in the financial sector was clear: among other things, they called for the IAS 39 accounting standard applicable back then to be replaced. Several publications, including *Chae et al.* (*2019*) discuss the shortcomings of the earlier, backward-looking standard that only supported provisioning for loss events that had already happened. The authors claimed that the credit risk losses suffered across the banking sector in huge amounts of discrete packages represented a major threat to financial stability, in an especially volatile and tense situation. To eliminate

[2] Altman Z-score: working capital/assets, retained earnings/assets, earnings before taxes and interest/assets, market value of shares/debt, sales revenue/assets.

such procyclical provisioning, the *International Accounting Standards Board* (IASB) introduced the currently applicable accounting rules in January 2018. IFRS 9, which underpins this study, also stipulates a forward-looking provisioning rule set that established three risk stages and is based on expected losses. This allows credit institutions to prepare for potential crises by increasing reserves and opens up new avenues for credit risk modellers in terms of developing various stage-migration models (see *Landini et al. 2019, Gross et al. 2020*, for example).

The literature is quite limited when it comes to presenting the credit risk simulation models used in stress testing, which is partly due to the practice only recently having been introduced and partly to the small number of entities conducting this activity. Stress tests assessing credit institutions' profitability and risk profile are typically run by banks themselves or the bodies supervising them, and thus the publications also come from this small group. The methodology used in practice which is most relevant for the European banking sector is provided by the *European Banking Authority* (EBA) and the *European Central Bank* (ECB), principally intended for internal use by national supervisors. *Gross et al.* (*2015*) offers relevant experience in terms of modelling, with their presentation of the practical application of the Bayesian model averaging. Ideas can also be gained from the practices of other European national competent authorities, among which the Dutch central bank's publication, *Daniels et al.* (*2017*), stands out due to its similar mortgage loan modelling methodology. The present paper adds to the stress testing literature best reflecting the features and risks of the Hungarian banking sector, using Hungarian data from the household sector, in contrast to the majority of publications that have mainly focused on corporate clients until now. With respect to the latter, *Lang and Stancsics* (*2019*) and *Horváth* (*2021*) certainly deserve mention. They address the corporate segment of the credit risk section in the MNB's stress tests. While the former approaches the banking sector from the macroprudential side, establishing stages based on the number of days past due and then estimating transitional probabilities with the model, the latter uses a logit model utilising client and macroeconomic data to augment the framework of the supervisory stress test.[3] Presentation of the literature relevant for this study ends with the comparison to the model in *Banai et al.* (*2014*), which is similar to the methodology described below, inter alia, in terms of the database used and the incorporation into the stress testing framework. The differences are partly due to the fact that while the aforementioned authors include the deal and client characteristics enabling risk categorisation in the same model as the time series variables, in this work it was considered better to include them in two different models on account of the

[3] For a summary on the supervisory stress testing framework, see the MNB's latest methodological handbook, 'The Internal Capital Adequacy Assessment Process (ICAAP), the Internal Liquidity Adequacy Assessment Process (ILAAP) and their supervisory review, and the Business Model Analysis (BMA)'.

methodological features of supervisory stress testing. The other main difference lies in the predictor variable, owing to the introduction of the new accounting practices discussed above. While *Banai et al.* (*2014*) focused their model the probability of default, this paper examines the sensitivity of the transitional probabilities between the stages.

The paper is structured as follows: *Section 2* presents the risk categories based on loans' deal and client characteristics, describing the database used for modelling, the selection of variables as well as the result of clustering. After this, the time series modelling framework of the estimated PDs along the resulting risk categories is illustrated, before shifting the focus to the evaluation and backtesting of the results in *Section 3*. The main thrust of the paper is *Section 4*, describing the steps of converting the modelled PDs into transitional probabilities across stages. *Section 5* summarises the conclusions.

2. The credit risk classification framework

In line with the above summary, the first part of this section mainly focuses on presenting the parameters of the database used and the characteristics of the available variables, to provide a solid basis for establishing the risk clusters described in the second half of the section and the time series models in later sections.

2.1. The database used and data cleansing

The modelling uses a database containing three of the eight largest credit institution groups operating in Hungary based on balance sheet total, using their individual reporting on client and deal characteristics at the time of application, while also incorporating features that change over time. The data were shared by the three institutions with the MNB for research purposes. The dataset includes all loans to households from the three banks in question between December 2004 and December 2018, covering an entire business cycle. Development of the deals over time can be traced at a quarterly frequency. Among the submitted data, mortgage loans include both housing loans and home equity loans, the latter of which comprised a larger share of household loans when the 2008 global economic crisis erupted, but still account for over 10 per cent of the total volume, making their detailed credit risk modelling warranted. However, a large portion of the mortgage-backed loans include housing loans, which also account for a massive share within total household lending, at around 50 per cent. Unsecured household loans and those with collateral other than real estate are not covered by this paper. The database includes more than 9 million observations, with the developments in around 370,000 individual deals over time.

The descriptive statistics of the variables can be found in *Table 4* of the *Annex*, showing that several deal and client characteristics required data cleansing due to missing and/or outlier, probably misreported, values. Data cleansing was conducted using three main strategies. In the case of the variables where the modelling was complicated only by missing values and this only concerned a negligible number of cases (no more than one-thousandth of the observations), the observations were deleted. With the variables where outlier values were also included besides missing information, the appropriate distribution was achieved by rescaling the data points and dragging them back to the percentile yielding realistic values.[4] The third technique, which potentially influenced the modelling the most, was used heavily in the case of the variables where the share of missing values was not large in percentage terms but above the negligible limit. In such cases, following the best-performing method based on *Little and Rubin* (*2002*), which looked at data cleansing techniques, the data missing in the quarters in question were filled in with the average of the variables concerned[5] observed in the relevant period.

According to *Acuña and Rodriguez* (*2004*), the treatment of missing data becomes problematic at over 5 per cent of the total sample and only affects the interpretation of the results from over 15 per cent. Fortunately, no shortcomings in the variables crossed any of these thresholds, and although data cleansing was performed to improve the accuracy of the results, no major effect is attributed to this from here on. For a comprehensive description of the data cleansing techniques, readers are referred to the descriptive statistics.

2.2. Predictor and explanatory variables

In addition to the study's direct credit risk contribution to supervisory stress testing, another aim is to confirm the assumption that the household loans disbursed in Hungary (in this case: mortgage loans) have improved considerably compared to the situation before the last financial crisis in terms of the distribution of risks. This may be driven by various factors, in particular the government and regulatory measures from recent years,[6] but banks' risk appetite has also changed in the meantime. The impact of debt cap regulations[7] on household lending was addressed by, among others, *Fáykiss et al.* (*2018*), pointing out that they did in fact achieve their goal, and thus the structure of lending was preserved, while the riskiest loans were crowded out. The secondary objective of the paper is to approach this phenomenon,

[4] Client age was limited between 18 and 80; the thresholds were 0–100% for the PTI and 0–200% for the LTV; the loan amount was capped at HUF 140 million, while the maturity period was limited to 40 years.
[5] Such missing data were only observed in the case of the PTI, the LTV and the transaction interest rate.
[6] E.g. forced conversion of FX loans, debt cap regulations (loan-to-value ratio, payment-to-income ratio)
[7] MNB Decree No. 32/2014 (IX. 10.) on the regulation of the payment-to-income and loan-ro-value ratios

combined with the change in banks' overall risk appetite, from the perspective of mortgage loans' PD, which is expected to show a decreasing trend outside the PIT (point-in-time) view, meaning a lower PD even in the TTC approach in recent years.

At the time of publication, the stress test used by the MNB's supervisory function calculated credit risk loss under the assumption that the loans amortising over the two-year stress scenario are replaced with the same risk profile. In practical terms, this means that if a 30-year-old mortgagor with a college degree and net income of HUF 300,000 at the time of the loan application repays their loan during this two-year period, they are replaced with a debtor with equivalent characteristics, which guarantees the stability of the risk composition and the loan portfolio. Of course, the size of the loan portfolio can also be tweaked in the stress scenario by adding the appropriate dynamics in line with the macroeconomic environment, just as in the stress test, however, the portfolio's risk profile stays constant in line with the methodology in use at the time of publication. To warrant any change in this, first it has to be known whether such risk consolidation was observable over time, and its extent is also important to develop the appropriate methodology. With this in mind, instead of applying panel regression estimation using macroeconomic and individual deal and client characteristics (e.g. pooled OLS), a two-step modelling approach was used, making the above-mentioned phenomenon better observable and more easily measurable. This represents one of the greatest differences as compared to the household PD model of *Banai et al.* (*2014*).

First, the loans were classified based on their underlying risk and then time series modelling was applied to them. Initially, an accurate definition of default, a variable measuring risk well, had to be given (as the database did not contain such a field), and it had to be quantified, which was eventually calculated with the formula:

$$Default = \begin{cases} 1, if\ DPD_0 < 90\ and\ (DPD_1 \geq 90\ or\ DPD_2 \geq 90\ or\ DPD_3 \geq 90\ or\ DPD_4 \geq 90); \\ 0 \end{cases}$$

where the subscript shows the number of quarters since the starting point, and DPD (days past due) denotes the number of days elapsed since the loan repayment fell due. Thus, the variable can take one of two values (the transaction either defaults or not): it takes 1, meaning a default, if a client which was performing at the start of the period is late on their loan repayment by at least 90 days any time during the next year, irrespective of whether the late payments were made by the end of the one-year period or not. Therefore borrowers cannot exit default during the year, which is consistent with the assumptions in supervisory stress testing. The application of the above rule yielded 69,205 defaults, representing just over one-sixth of the entire database.

Since the modelling aims to enable supervisory stress testing to provide the most accurate possible picture of the credit risk of the credit institutions and credit institution groups operating in Hungary,[8] the projected migration probabilities should reflect the different risk levels in banks' portfolios. Accordingly, the modelling was divided into two: 1) creation of homogenous groups, and 2) modelling the established groups (as portfolios) with time series methods. The first step helps eliminate the procyclicality of the modelling by including various characteristics, which is necessary because of the Pillar 2 guidance, the end product of the supervisory stress test. It can also prevent us from obtaining a less-than-accurate picture of a bank that uses a stricter-than-average credit scoring system or tightens its system in the meantime.

In practice, this micro-level approach can be achieved by creating risk groups other than the IFRS 9 stages, based on deal and client characteristics. Along the default rate (DR),[9] characteristics and explanatory variables need to be chosen that can best separate the loans according to riskiness. To narrow down the group of variables with potentially strong explanatory power in the database, the relationship between the characteristics and the corresponding average through-the-cycle DR independent from time was examined. The charts on these relationships can be seen in *Figure 4* of the *Annex*. The charts were prepared to answer two questions. First, whether the relationship between the explanatory variables and the DR was strong and varied in space, in other words whether the range of a given characteristic was clustered around various average DRs. And second, whether this relationship was linear or not. *Jagric et al.* (*2011*) used bank data from Slovenia to model the relationship between credit risk and explanatory variables, finding that non-linear relationships have a huge impact on model performance. To achieve linearity and ensure easier and more accurate modellability, several continuous variables with broad ranges were transformed into categorical variables.

The next paragraph addresses the variables that required closer inspection not only because of the test statistics and preliminary intuition but also because the features of the database. In the case of the loan-to-value ratio (LTV),[10] it was suggested that its risk segmentation capacity, detected by *Holló* (*2009*) in his work on household mortgage loans, may have been distorted after the crisis, especially due to the introduction of the regulations that took effect around 2015. In theory, this would mean that although during the crisis and directly thereafter those loans which were disbursed with a higher LTV could also have a higher payment-to-income ratio (PTI),[11]

[8] Although the outcome of the stress test is mainly influenced by credit risk costs, in practice, market, counterparty, operational and profitability risks are also quantified during an assumed potential economic downturn.
[9] The proportion of DR weighted for exposure over the entire period
[10] Loan amount / current value of the collateral
[11] (Monthly) loan repayment / verified total net monthly income of the loan applicant and the co-debtors in the loan contract

this may have potentially turned around later. According to the hypothesis, this may have been caused by banks becoming more risk-averse due to regulatory measures but continuing to lend to clients with a lower PTI at a higher LTV. The hypothesis was easy to examine using the data, and it turned out that the theory has no basis that could be detected with the current modelling database, as any given LTV has similar PTI levels in all periods, which rises as the former increases, i.e. deteriorates. This is also confirmed by the fact that the coefficients of the regressions without an LTV do not deviate from those observed in the equation that include the variable. The other interesting variable with a seemingly strong separating power was the time elapsed since the loan application, which could be used quite intuitively: the further along the debtor in repayment, i.e. the more they paid back from the loan, the more likely they are to continue making the repayments until maturity. When the DRs are arranged based on the time elapsed, there was a turning point at around 5–6 years, where the DRs suddenly started to decrease sharply. The use of the variable and the accuracy of the turning point is confirmed by *Balás et al.* (*2015*), who sought to build a cross-sectional model that included the explanatory variables best explaining default risk. Still, the application of the variable was met with some doubt, as even a simple analysis showed that in the 1–5-year range, due to the features of the time series and the dataset, the high DR could also be explained by the fact that in 2008–2010, when most of the defaults occurred, over 90 per cent of the loans in the sample were younger than 5 years. In other words, the DR does not reflect the risk profile of the transactions, but simply the age at which they entered the crisis. Nevertheless, in the end the literature, test statistics, the regressions performed[12] and the inclusion in the modelling of the macroeconomic data varying over time that will be presented below proved to be convincing, and it was decided that the time elapsed would be used.

Eventually, the average annual interest rate and the year of loan disbursement (vintage) were not included among the modelling variables based on the figures and the test statistics. Ultimately, 10 of the 12 potential explanatory variables in the short list shown in *Figure 4* of the *Annex* were retained: (*adjusted*) *loan amount,*[13] *educational attainment of the client, age of the client, time elapsed since borrowing, time to maturity, existence of a co-debtor, PTI, LTV, loan type, loan currency*. Apart from the time elapsed, all variables are unchanged over time (with static correlations deliberately retained), so each of them reflects their status at the time of disbursement.

[12] It was examined whether the inclusion of the time fixed effects (basically the disbursement period dummies) in the logit model divert the time elapsed parameters, and as both the coefficient and the standard error proved to be stable, the use of the variable was considered justified.

[13] To maintain the time value, the future value of the pre-2018 disbursements was used throughout, which was produced using the growth rate of the cumulative sectoral average wage.

2.3. Establishing the risk categories

Before the separation, i.e. risk classification, the next step was a more detailed statistical analysis of the selected characteristics. Logistic regression (logit), the most widely used method in banks' risk management practices, was employed in further testing explanatory variables.

$$Y(default = 1, performing = 0) = G\left(\beta_0 + \sum_{i=1}^{n} \beta_i \cdot x_i\right)$$

where:

$$G(x) = \frac{e^x}{1 + e^x}$$

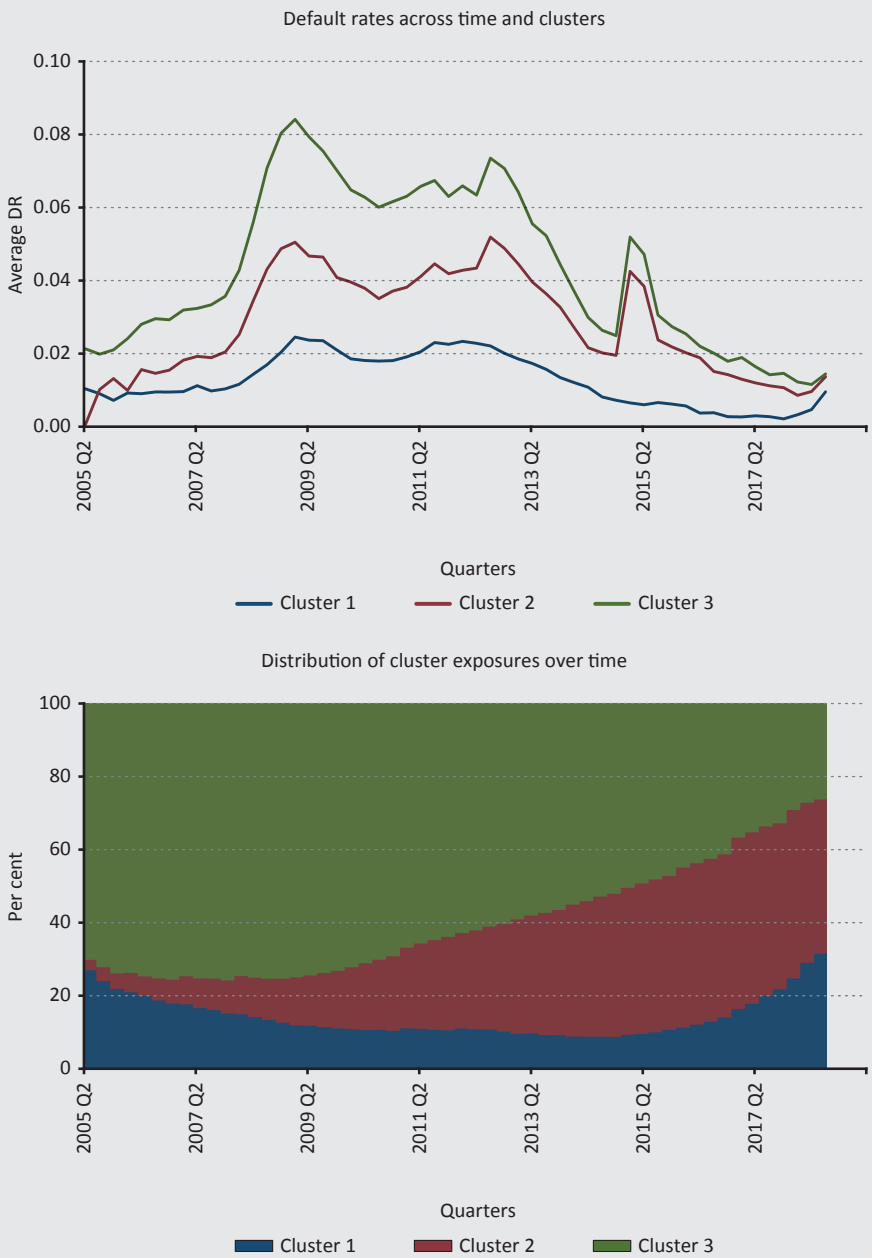
All of the explanatory variables in the model proved to be significant together and separately as well, and thus were in line with the earlier intuition that they have a strong separation power, and also with the purpose of the modelling. The results of the model and the statistical tests can be seen in *Table 5* of the *Annex*, while *Figure 5* of the *Annex* shows the ROC (Receiver Operating Characteristic) curve, which backtests the accuracy of the logit model, producing around 70 per cent, which is a relatively good result compared to similar models. Due to the relatively high number of characteristics involved, the extent of multicollinearity, i.e. the correlation among explanatory variables was also examined (see *Table 5* of the *Annex*). The test statistics show that the model has a strong correlation effect. Besides the potential multicollinearity, the variables' other characteristics also pointed towards transformation and dimension reduction. It was observed that the variables used for the separation were heterogeneous in terms of their distribution and range, which tallies with the above multicollinearity issue and the non-linearity problem affecting logistic regression. *McDonald et al.* (*2012*) showed that the non-linear relationship between predictor and explanatory variables that distorts logistic regression can be caused by the correlation between the various risk variables included in the model. To avoid this, the authors recommend the principal component analysis (PCA). This study also used principal component analysis to perform the transformation and dimension reduction. As proposed by *Kovács* (*2014*) for variables of varying standard deviation and measure, the continuous variables were first standardised, which satisfies the normality requirement for the distribution of data. Although the category variables do not have normal distribution and using them in principal component analysis is therefore controversial, several studies, including *Kolenikov and Angeles* (*2004*), have shown that their use does

not lead to a great degree of distortion, especially when combined with multiple continuous variables. This principal component analysis produced 4 transformed variables from the 10 existing deal and client characteristics.

After the PCA, the focus was shifted to classifying the loans based on risk, for which a widely used dimension reduction process, cluster analysis, was employed. But first, it was necessary to examine what type of algorithm was permitted by the chosen variables and the dataset. The literature usually ties the choice of methodology to the amount of data and outliers. The sample size in this study makes non-hierarchical cluster analysis an obvious choice, and one of the most popular types, the *k*-means method was picked for creating the groups. This algorithm assigns all data points to the cluster whose centre falls nearest to them. The centre is usually the average of a (random) group of points, and it can typically be applied to points in continuous η-dimensional spaces, so the variables should be collected on the same scale. One feature of the methodology is that during an out-of-sample, idiosyncratic clustering of another bank's portfolio, the same number of groups will be produced as measured in the sample, which may have a distortive effect when supervisory stress testing is performed for relatively homogenous client structures, for example banks lending only to good clients. To reduce or even eliminate any potential distortion, the clusters are calibrated at the banking sector level, which allows individual banks to have very different cluster structures than the average, if warranted by their clientele.

The cluster analysis was performed using the arising principal components, and although the results would have warranted the creation of four different risk group, two clusters produced very similar distributions for the past probabilities of default, so they were merged, and three different clusters were established. The results of this process are summarised in *Table 1*, while the statistics for the PCA and the *k*-means cluster analysis can be seen in *Table 6* and *Figure 6* of the *Annex*. The upper panel of *Figure 1* illustrates that the categories are well-differentiated based on their probabilities of default over time, so the classification produced results in line with expectations.

Figure 1
Variation of the PD (upper panel) and share (lower panel) of the clusters over time



The lower panel of *Figure 1* also shows the share of the different clusters in the period under review. The rapid reduction of Cluster 3 is the first thing that stands out in the chart. The share of the cluster holding the riskiest loans clearly drops from approximately 70 per cent around the 2008 financial crisis to below 30 per cent by the end of the modelling period. This is consistent with what *Bodnár et al.* (*2014*) observed in their paper on the relationship between financial crises and lending. They found that the run-up to crises is usually characterised by the build-up of an excessive amount of bad loans, as seen in Hungary in connection with the household sector's FX loans. However, according to the database used here and the lessons from *Figure 1*, the distribution of loans was worse than today not only in terms of denomination, but also regarding other deal and client characteristics. *Figure 1* also illustrates two interesting events, especially in Clusters 1 and 2, and both of them were tied to government measures. The first appears around 2011, when the share of bad debtors starts to decline fairly steeply, which is attributable to more restrained bank lending. But it can also be seen that the proportion of the best debtors is stable or changes only slowly, which is due to the low loan penetration and the slight dilution of the mortgage loan portfolio in the post-crisis period. This tallies with the claim of *Balás et al.* (*2015*), namely that the early repayment scheme launched in 2011, allowing borrowers to pay off their debt for free, mostly benefitted the best debtors. The second turning point, leading to a larger share of higher-quality transactions, came around 2015–2016. This coincided with the introduction of the requirement to use the LTV and the PTI during credit scoring, whereby applicants who wish to become overindebted are not even admitted to the portfolio, and thus – coupled with the positive effects of an uptick in demand and falling interest rates – the share of good debtors began to rise.

Granular data also show the type of loans that are more likely to be removed from banks' mortgage loan portfolios with this process. While the proportion of those with at most a secondary school diploma is 35 per cent in the least risky Cluster 1 over the entire period, the same figure is 79 per cent in Cluster 3. A similar distribution can be observed for all variables included in clustering. For example, 64 per cent of FX loans and 84 per cent of home equity loans are in the riskiest cluster. The same holds true for continuous variables. The transactions in the best Cluster 1 have a PTI that is 26 percentage points higher on average than in the worst group, while the loan amount (HUF 7.6 million–10.1 million) and time to maturity (187 months–250 months) also exhibit a different distribution. Interestingly, as regards the LTV and the time elapsed, Cluster 2 has the highest average values, but it can also be observed that the other characteristics of these outliers are mostly below-average from a risk perspective, and therefore their placement in the middle category is justified.

3. Time series modelling framework using risk groups

This section describes the other key part of the modelling framework's backbone, namely dynamics, which is represented in the work after a static view of clustering. Similar to the previous section, this section starts with the description of the database helping the modelling, followed by the presentation of the time series models of PDs, before ending with robustness analyses and backtesting of model.

3.1. Data used

Any given portfolio's overall riskiness can be estimated based on deal and client characteristics, yielding a TTC-type measure. This helps differentiate banks from each other according to their vulnerability in line with the prevailing conditions, producing a sort of ranking, but the measurability of the model's response to stress arises from channelling in variables depending on the business cycle. Such procyclical variables can be macroeconomic indicators that change over time and capture the prevailing economic climate of a country well. Yet the macroeconomic variables included in the mortgage default forecasting model should also have another major feature, namely the ability to capture the relationship between household debtors' propensity to repay and business cycles.

Linear regression models were employed to determine this relationship, linking the PDs of the various risk groups to the chosen macroeconomic variables. The choice of macroeconomic variables included in modelling was influenced by two factors. First, the results need to reflect the impact of stress on the PD of household mortgage loans, and even at the expert level, intuitive variables should be included. Second, by virtue of its prediction model nature, the explanatory variables need to be forecastable so that PDs can be estimated for later periods, even 2–3 years ahead. Only variables could be used for which forecasting was available. The latter requirement limited the analysis to 18 macroeconomic measures. The 1–4-quarter lagged values of these variables were also included in the model, to manage protracted effects, potentially drawn out over a year. The variables were first examined on an expert basis and then with a statistical approach; they are shown in *Table 1*.

Table 1
List of macroeconomic variables used in the modelling, their abbreviations and calculation methods

Variable name	Calculation method	Variable name	Calculation method
Households' net financial wealth (wealth)	at 2015 prices	Household's disposable income (hinc)	at 2015 prices
Inflation (infl)	(year-on-year)	EUR/HUF exchange rate (eurhuf)	average
Unemployment rate (unemp)	based on labour force survey	BUBOR-interest (bub3m)	3-month
GDP (gdp)	(year-on-year)	BUX index (bux)	at 2015 prices
Exports (exp)	at 2015 prices	Volatility of the BUX index (buxvola)	quarterly
Imports (imp)	at 2015 prices	EURIBOR interest (eurib3m)	3-month
Employment in the private sector (emp)	thousand people	Benchmark yield curve (gov1y, gov3y, gov5y, gov10y)	government securities market, %
Gross average earnings in the private sector (wage)	at 2015 prices		

Note: GDP and its subitems are seasonally and calendar-adjusted, balanced data.

The predictor variable sought to be estimated is the annual forward-looking PD for all three previously created clusters. To determine this, the defaults that can take [0,1] values calculated from the above formula on the basis of the number of days in default were aggregated for the individual dates and clusters in the database, then, using the share of the defaulting loans' exposures, the average DR was calculated for the period (see *Figure 7* in the *Annex*). In line with the predictor variable, the database of explanatory variables contains past values for 2004–2018.

3.2. The structure of the models, and the results produced

The PDs were forecast along the arising risk categories, by developing three regression equations in total. During this, the includability in the model based on the explanatory power, the interactions and the appropriateness of the time series were all evaluated. As a result of these examinations, the explanatory variables used for the regressions were differentiated once to achieve stationarity.[14] In the case of the predictor variable, it was proposed that, due to its limited nature, it could be stationary on a long time series, unlike standard economic time series, but this was

[14] A stochastic process is broadly speaking stationary if its joint distribution function is independent from time (*Matyasovszky 2002*).

not confirmed by the Dickey–Fuller test, so this time series was also differentiated. The regression equations that emerged were written with the standard structure:

$$\Delta DR_{annual\ average} = \beta_0 + \sum_{i=1}^{n} \beta_i \cdot \Delta x_i$$

where Δx_i is the change in the *i*th explanatory variable in the regression, and n denotes the number of variables.

Before picking the explanatory variables, the autocorrelation of the predictor variable's time series was analysed, in other words the explanatory power of the lagged values and their correlation with the actual period's values were examined. The autocorrelation tests produced a value within the significance level for the lagged values in the first 1–2 quarters in all clusters. But since the predictor variable includes annual PDs, it inevitably overlaps with the values of the next four quarters, and *Table 9* of the *Annex* shows that the Durbin–Watson alternative tests performed on the entire model did not confirm an autocorrelation, so the autocorrelation of the predictor variable within the year did not hamper modelling.

To select the macroeconomic variables necessary for forecasting the change in PD, first simple linear regressions were performed between the change of the predictor variable and of macroeconomic variables or their lagged versions. The variables that turned out to be significant based on the equations and the test statistics were merged, and then a backward[15] elimination method was used to pick the variables that remained significant even when they were together. During this process, special attention was paid not to exclude from the final models the macroeconomic variables that could potentially be eliminated due to the correlation between the explanatory variables (see *Table 7* of the *Annex*); accordingly, after the process was performed, every variable that had been filtered out was attempted to be reinserted into the model one by one, and the exclusion was only considered final after that. In the case of the variables that remained in the model, the correlation could not exceed 0.6, which was set as the critical threshold. The equations with the greatest explanatory power and robustness in the three clusters can be found in *Table 2*, while the corresponding test statistics are shown in *Tables 8, 9* and *10* of the *Annex*. *Table 2* also illustrates what differentiates the methodology presented here, in addition to the duration and current nature of the time series, from the assumptions in the MNB's macroprudential stress test as described in *Banai et al.* (*2014*). While the present study allowed the debtors with heterogeneous situations and riskiness to be affected differently by the various macroeconomic

[15] The selection process involves the following steps: 1) incorporation of all the variables logically related to the explanatory variable into the model; 2) calculation of the partial *t*-test values for the explanatory variables' parameters; 3) if the *t*-value of the variable with the lowest *t*-value is lower than the value at the given significance level, the variable is excluded from the regression; 4) constructing a new model with the remaining explanatory variables; 5) repeating this until only significant variables remain in the model.

variables, *Banai et al.* considered it appropriate to estimate the PD for all borrowers using the same external conditions. The results may support this idea, because from an economic perspective it can be deduced intuitively that for example the development of employment, which has an increasing coefficient along the different clusters, has a greater impact on the workers without a degree and employed in worse, more vulnerable and potentially only ad-hoc jobs than on those graduates who presumably have a more permanent position. It can also be observed that net wealth is important for those in the more vulnerable second and third clusters, while this variable was not even included in the equation for the most reliable debtors based on their repayments. Similarly to the previous observation, this is perhaps explained by the fact that people in more secure jobs earn more (which is also reflected in the PTI levels) and rely more on their earned income than on their existing wealth.

Table 2
Results of multivariate linear regressions determined with the backward selection process

	Clusters		
	1	**2**	**3**
Predictor variable / Explanatory variables	*d_DR_y*	*d_DR_y*	*d_DR_y*
d_emp	–0.05367**(0.0260)	–0.14823**(0.0619)	–0.28462***(0.0886)
d_exp	–0.01632**(0.0067)		
l1_d_gdp	–0.00028**(0.0001)		
d_gov10y	0.00044**(0.0002)		
d_bub3m	0.00145***(0.0003)	0.00229**(0.0009)	0.00549***(0.0012)
d_wealth		–0.05383**(0.0226)	–0.08171**(0.0323)
l3_d_gov1y		0.00193***(0.0006)	
l1_d_bux		–0.01027*(0.0055)	
l3_d_hinc			–0.08444**(0.0330)

*Note: *p<0.1; **p<0.05; ***p<0.01. Standard errors are shown in brackets. 'd' is the annual change in the variable, 'l' is the quarterly lag, while 'y' indicates the annual nature of the probability of default.*

From a credit risk perspective, the sample covers quite an eventful period, replete with government and regulatory measures that had a major impact on the risk segmentation of household loans and thus also the development of PDs. Perhaps the largest government measure that caused a huge fluctuation in the historical time series of PDs was the forced conversion of FX loans that coincided with the settlement. In the short run, these steps led to a temporary rise in PD, followed by a decline. Several studies have been published on this phenomenon from 2011–2012. *Sepsi* (*2014*) attributes the rise to the fact that between the announcement of

the government decree and the actual implementation of this measure debtors may not have cared about paying their upcoming repayment instalments, as they knew that they would be able to make full repayment soon. *Balás et al.* (*2015*) explain the temporary spike in PDs by claiming that the banking system mostly lost mortgagors who performed well, which may have led to a shrinking of the denominator of PDs, without triggering any change in the numerator. The situation was similar with the forced conversion of FX loans, as there the denominator diminished as the value of FX-denominated debt declined. Two solutions were identified for smoothing the spikes in *Figures 1* and *3*: the first is the inclusion of a dummy variable[16] in the model, potentially covering the break in the trend of the time series that could presumably be explained only incorrectly with macroeconomic variables. The other possible solution is the truncation of the time series, whereby the fairly volatile quarters of 2015 are removed from the model estimation. In the end, the truncation of the time series was used, for two reasons: first, the issue only affected one year in the time series spanning 14 years, and second, the case for using the dummy variable was not convincing statistically or from the perspective of forecasting and backtesting, as it lagged behind the second solution in both scenarios.

3.3. Cross-validation, robustness analysis

During testing, the results were examined using two approaches, which are presented in this subsection. The first and most important step was to assess the stability of the models by checking the stability of the coefficients and significance levels of the explanatory variables included. The aim was to prove that the model assigns similar coefficients to the variables upon cross-sectional and time series shrinking of the sample, and also when leaving out certain variables from the equation, while preserving the significance of the remaining macroeconomic variables. To aid implementation, random sampling was used before modelling to remove 25 per cent of the existing total dataset. Having performed the cross-validation on this test sample, it was found that the 10 per cent significance level (*p*-value) determined as critical for testing is breached by only a negligible number of variables used in the three equations. After the cross-sectional data truncation, the time series of the modelling database was reduced by half, with similarly positive results. The robustness analysis of the models ended with the exclusion of a few variables. In this case, the significance levels remained within the critical 10 per cent with the exception of one item, and the coefficients of the explanatory variables did not deviate substantially from the values observed in the original models. The details of the analyses can be seen in *Table 11* of the *Annex*.

[16] It takes a value of 1 in the quarters where the break in the trend occurs (2014 Q4–2015 Q4) and 0 in all others.

In the second round of testing, the accuracy of the models was assessed by comparing actual PDs with the values predicted by the model. The sample was chosen to be the first three years of the 2008 financial crisis, for two reasons: first, as this is a stress forecasting model, a volatile period in PDs was necessary, and second, supervisory stress testing usually simulates similar downturns. The backtesting results are shown in *Figure 2*, where the model's estimates move in tandem with the actual data, without any major deviations.

Figure 2
Actual and modelled PDs by clusters, backtested on the data from the 2008 crisis

Therefore, based on the cross-validations and backtests performed that also measure robustness and the goodness of the models, the models can appropriately capture the shifts in macroeconomic variables over time as well as the separating effect of the deal and client characteristics that form the basis of risk segmentation.

4. Transforming PDs into the transitional probabilities of stages

The forecasting of PDs would only allow performing and non-performing transactions to be differentiated, which would have been insufficient as the new accounting standard IFRS 9 became widely used. This section presents how the two

groups categorised in terms of the loan repayment performance of debtors are turned into four credit risk stages that better separate clients' solvency.

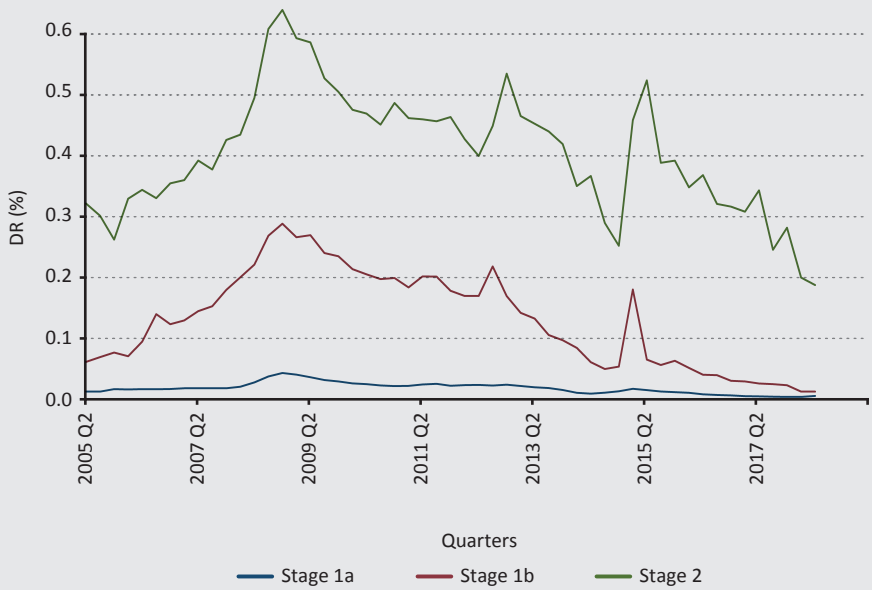
4.1. Creating stages

In accordance with the new accounting standard recommendation (*IASB 2013*), three credit risk categories must be established. The first ('Stage 1') comprises the transactions that are not past due or only slightly so (by no more than 30 days). The interim category between non-performing and performing transactions (Stage 2), which is one of the features that sets apart IFRS 9 from the previous accounting standard,[17] includes the loan contracts past due by more than 30 but no more than 90 days. Based on the recommendation of the accounting standard, several transaction and subjective characteristics[18] can be taken into account while creating the groups. This is also confirmed by the experience from ICAAP analysis, namely that there are almost as many rules for defining Stage 2 as there are banks. The present model follows the Stage 1 logic due to its comparability, simplicity and the availability of the data, and only the number of days past due was taken into account while creating the group, with a value of 31–90 days. Finally, the non-performing category ('Stage 3') was created as well. It contained the transactions that were more than 90 days past due at the time of observation.

An additional analysis according to the distribution of the number of days past due highlighted that the riskiness of Stage 1 was too heterogeneous for uniform modelling. *Figure 3* shows that Stage 1 clients who were late with their payments by more than 30 days at least once since the disbursement were more likely to do so again than their always performing peers. It can also be seen that the transactions in the interim category (Stage 2) are much more likely to default on average than any of their Stage 1 peers, and they also respond stronger to economic fluctuations. Consistent with this phenomenon, but in contrast to the IFRS 9 recommendation, the creation of four, rather than three, risk categories was warranted. The first group ('Stage 1a') included the best transactions that were currently past due by no more than 30 days and, in contrast to the usual categorisation in the banking sector, also performed well before the time of observation, so they were never more than 30 days past due since origination. The second Stage 1 subcategory ('Stage 1b') includes the transactions that were not more than 30 days past due at the time of observation, but had been at least once during their lifetime.

[17] IAS 39 only differentiated between two risk categories: performing and non-performing. Directive 2006/48/EC of the European Parliament and of the Council was the first to include an official definition of non-performance (default).
[18] Restructuring, difference between initial and observed PD values, risk rating, expert judgement

Figure 3
Average annual PD of performing mortgage loans of different risk categories



4.2. Forecasting transitional probabilities

As four risk groups were created from the original two, the number of cross-group migration probabilities sought to be forecast also increased considerably. In line with the stress testing methodology of the supervisory authority and the *EBA* (*2021*), there is no exit from default or Stage 3, so that direction was not explored. However, the Stage 1a–Stage 2, Stage 1a–Stage 3, Stage 1b–Stage 2, Stage 1b–Stage 3, Stage 2–Stage 1b, Stage 2–Stage 3 directions are all important for accurately forecasting credit risk losses. The transformation of the PDs is presented in this subsection.

The transformation was performed based on the methodological guidelines prepared by the ECB. The document was drawn up for the EU-wide EBA stress test covering the largest banking groups, strictly for the internal use of national competent authorities, helping to control and compare the internal models of participating banks, such as OTP Group from Hungary, during the quality assurance process performed as part of the exercise. In the ECB's model, the PDs are only used directly for forecasting Stage 1–Stage 3 (TP^{1-3}) and Stage 2–Stage 3 (TP^{2-3}) migrations, based on the below formulas:[19]

[19] Of course, in line with the section's introduction, the Stage 1 loans were divided into two groups, in contrast to the ECB's practice, breaking up the Stage 1 formulas into 'a' and 'b' parts.

$$TP_{T_0+h}^{1-3} = \Phi\left(\Phi^{-1}\left(TP_{T_0}^{1-3}\right) + \Phi^{-1}\left(DR_{T_0+h}\right) - \Phi^{-1}\left(DR_{T_0}\right)\right)$$

$$TP_{T_0+h}^{2-3} = \Phi\left(\Phi^{-1}\left(TP_{T_0}^{2-3}\right) + \Phi^{-1}\left(DR_{T_0+h}\right) - \Phi^{-1}\left(DR_{T_0}\right)\right)$$

where T_0 denotes the values of the starting period, ϕ is the cumulative distribution function of standard normal distribution, while *h* shows the number of periods since the starting point. The initial (T_0) probabilities are calculated based on the actually observed exposure migrations across stages in the previous year (actual year). The formula determining future, hypothetical TP^{1-3} transitional probabilities is of course duplicated when Stage 1 is broken down into two, so the probability of migration is calculated for both performing and past due transactions. The calculation is performed separately for all three clusters, yielding nine different numbers for the probability of the loans in the given group becoming non-performing over the course of the next year.

Forecasting the probability of migration to the non-performing category is also paramount, as Stage 1–Stage 2 and Stage 2–Stage 1 forecasts are also based on that. This was estimated using a simple linear regression relationship, with the following formulas:

$$\Phi^{-1}(TP_t^{1-2}) = \beta_0 + \beta_1 \cdot \Phi^{-1}(TP_t^{1-3})$$

$$\Phi^{-1}(TP_t^{2-1}) = \beta_0 + \beta_1 \cdot \Phi^{-1}(TP_t^{2-3})$$

where first the coefficient of the past covariance of TP^{1-2} and TP^{1-3} (β_1) is estimated, then, assuming that distributions remain stable over time, the value of TP^{1-2} is projected using this coefficient through the previously forecast TP^{1-3}. The methodology is similar for TP^{2-1}: the only difference is that this migration is complemented by TP^{2-3} as the explanatory variable. When estimating TP^{1-2} and TP^{2-1}, unlike in the transitions TP^{1-3} and TP^{2-3}, the sample is not broken down into clusters, since the different risks of these groups are incorporated through actual data and the explanatory variables of the regressions.

Table 3
Results of the univariate linear regressions between the transitional probabilities across stages

Explanatory variables	Predictor variables		
	d_invn_s1as2_y	*d_invn_s1bs2_y*	*d_invn_s2s1b_y*
d_invn_s1as3_y	0.52438*** (0.0854)		
d_invn_s1bs3_y		0.23393*** (0.0678)	
d_invn_s2s3_y			–0.69007*** (0.1002)

*Note: *p<0.1; **p<0.05; ***p<0.01. Standard errors are shown in brackets. 'd' is the annual change in the variable, 'invn' is short for the inverse of the cumulative standard normal distribution, while 'y' indicates the annual nature of the transitional probabilities.*

In the end, the transitional probabilities were differentiated once to ensure the fulfilment of the stationarity requirement of the variables, which is vital when using time series regressions. The results of the models designed as described above can be seen in *Table 3*, which also shows, among other things, that while the coefficients of TP^{1-3} take positive values in regressions, in line with the preliminary intuition, and thus a positive correlation is assumed with TP^{1-2} values, TP^{2-3} has a negative value, showing that two processes moving in opposite directions are examined there.

5. Summary and conclusions

At the end of the entire modelling process, several conclusions and lessons can be drawn that can help to more accurately assess the risks related to the mortgage loan portfolios of the credit institutions and credit institution groups operating in Hungary as well as facilitate the appropriate stress testing of such. One of these, the reason for which was not this clear from the earlier supervisory stress testing exercises, is that under the current conditions and loan portfolios, and with a macroeconomic shock similar to the 2008 global crisis, the same levels of credit risk losses cannot be estimated for Hungarian banks. There are two reasons for this:

1. prior to the crisis, initial DRs were much higher than what can be observed in the period before the publication of the study; and

2. partly due to the denomination of the loan, but partly due to other factors, a riskier and lower-quality portfolio built up before the turbulent period, which thus entailed a much greater potential PD.

The first reason could be the result of the second to some extent, but this is also partly related to the lower or more limited levels of financial awareness, the psychology of loan repayments and lending controls in earlier times. Another conclusion is that a much more accurate picture can be gained about the credit risk of different banks that originate varying qualities of loans if loan portfolios are stressed using transaction-level models and various characteristics. It has been observed that the difference in PDs between the riskiest and the best client groups can amount to several percentage points. Using the above-mentioned loan characteristics and creating a two-step model could also potentially contribute to a more accurate estimate through the heterogeneous use of macroeconomic variables. The results of the model show that with loan repayments the indicators that shape the PDs of the debtors classified into the different risk categories are mostly influenced by the stability in earned income and the extent of relying on various assets.

The models therefore help in calculating the component with the greatest influence on the stress scenario results, i.e. credit risk costs. The lessons learnt from the separation of the through-the-cycle step using lending characteristics can be used to decide, by touching on the dynamics of the stress test, whether to make the loans disbursed under the stress scenario consistent with the maturing ones, or the portfolio's credit characteristics should be modified, and if so, in what direction and to what extent.

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Appendix

Table 4
Descriptive statistics of the explanatory variables used from the database

Variable	Observations	Average	Standard deviation	Min	Max	Data cleansing
termek (loan type)	9,350,798	1.5	0.5	1.0	2.0	
kesnap (days past due)	9,350,798	110.2	405.1	0.0	4,794.0	
szla_deviza (currency)	9,350,798	2.0	0.5	1.0	3.0	
szla_futamido (repayment period)	9,350,798	226.5	82.0	8.0	480.0	
szla_ltv (ltv at disbursement)	9,350,385	0.5	0.2	0.0	9.5	deletion, scaling
ugyf_rendjov (disposable income)	9,350,798	135,017.7	194,403.8	0.0	82,000,000.0	
ugyf_kor (age)	9,350,798	37.5	9.8	1.0	152.0	scaling
ugyf_nem (gender)	7,689,811	1.4	0.5	1.0	2.0	
ugyf_eltartott (dependent)	9,331,701	0.8	1.0	0.0	32.0	
ugyf_kereso (number of earners in family)	9,350,798	1.6	0.6	0.0	25.0	
ugyf_torlkiad (repayment)	9,308,471	29,192.2	283,734.4	0.0	269,000,000.0	
ugyf_iskveg (education)	9,343,639	2.3	0.5	1.0	3.0	deletion
ugyf_csalallapot (marital status)	9,346,990	1.7	0.7	1.0	3.0	deletion
adostars (co-debtor)	9,350,798	0.6	0.5	0.0	1.0	
jaras (district)	9,326,903	91.8	57.4	1.0	198.0	
szla_arfolyam (exchange rate)	9,350,798	147.7	75.3	1.0	316.0	
szla_kamat (interest rate)	9,350,798	5.9	2.2	2.0	19.5	
pti_felv (pti at disbursement)	8,717,907	7.2	741.6	0.0	230,674.0	average, scaling
felv_hitelossz (loan amount)	9,350,798	11.9	9.3	0.5	345.0	
vintage	9,350,798	575.8	27.9	524.0	707.0	
eltelt_ido (time from disbursement)	9,350,798	52.2	37.7	0.0	183.0	

Note: The table shows the missing data in the different variables as well as the data cleansing method used.

Figure 4
The relationship between the chosen deal and client characteristics as well as the corresponding PDs

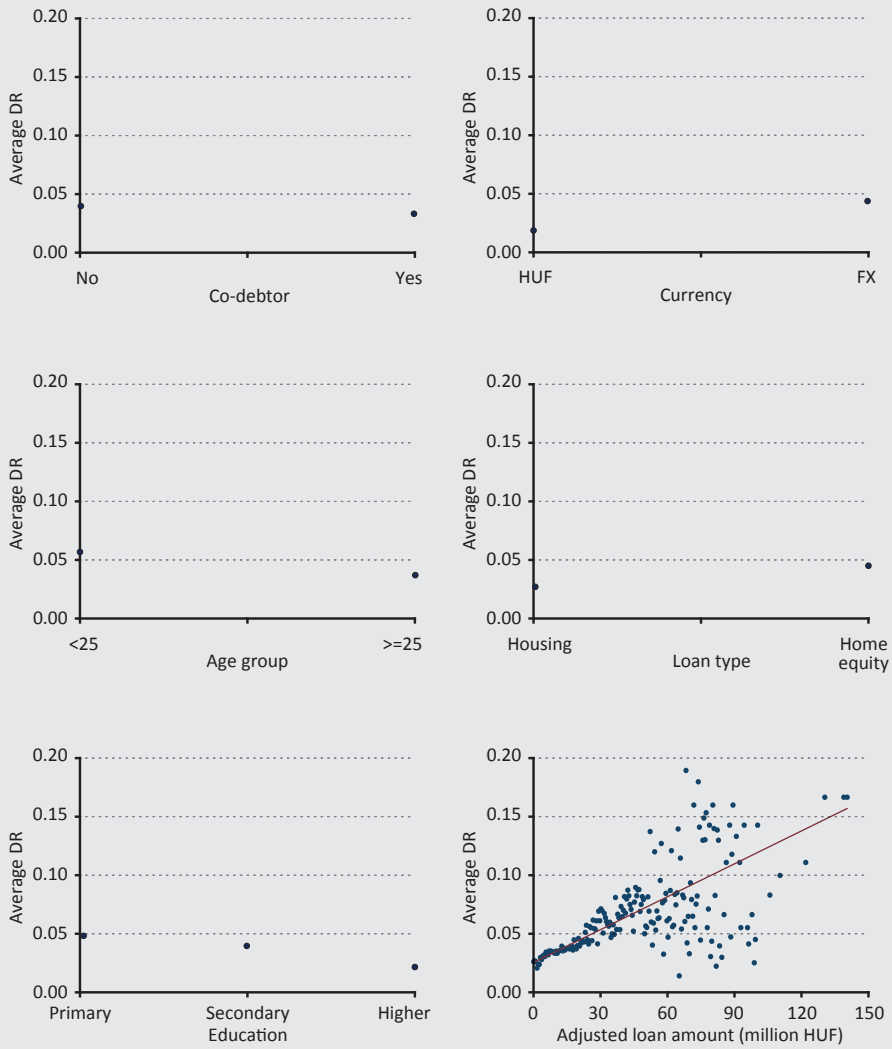
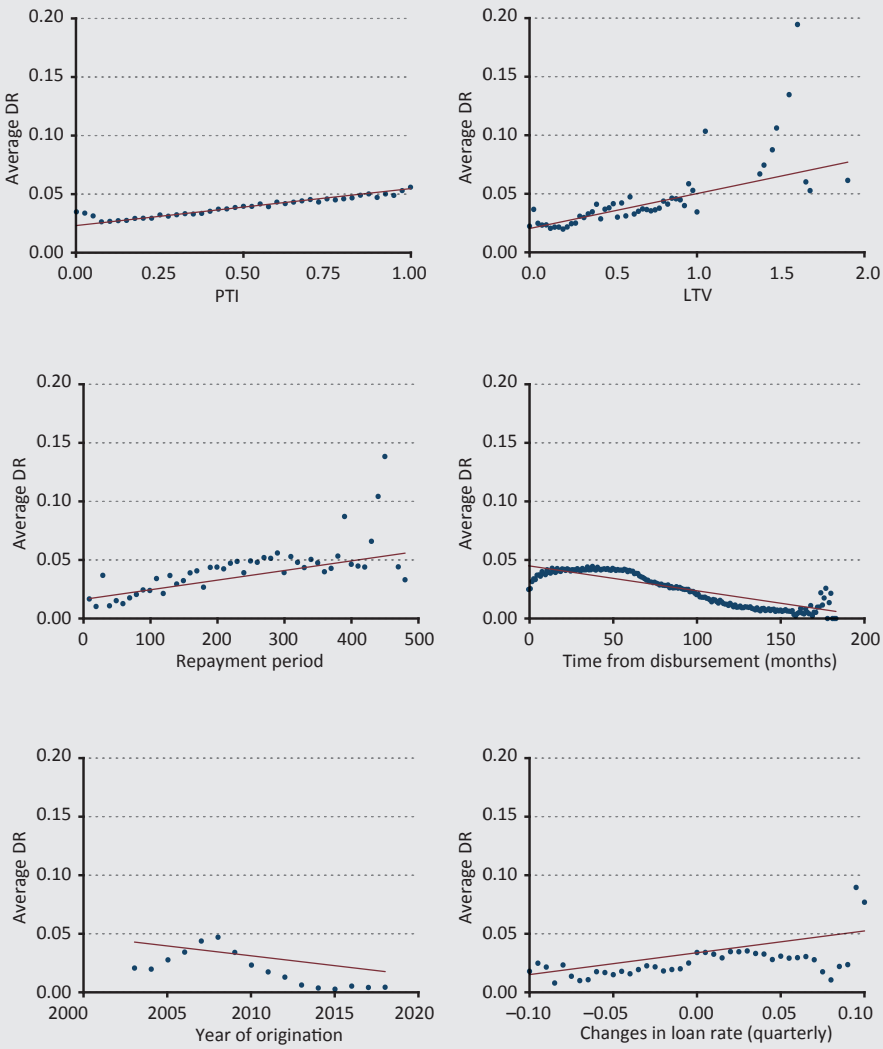


Figure 4
The relationship between the chosen deal and client characteristics as well as the corresponding PDs (part II)



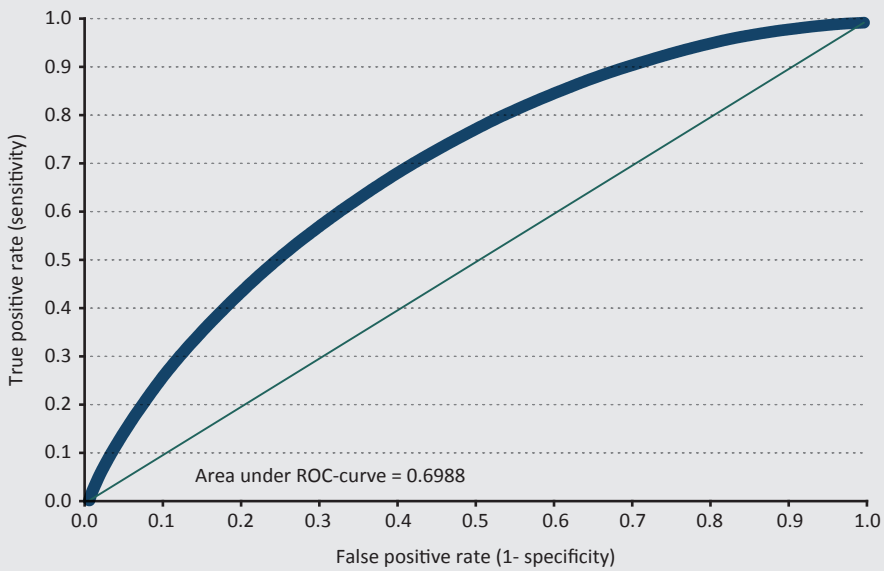
Note: In the case of continuous variables, the figure also shows the line fitted based on the simple linear regression of the given variable and the average PD.

Table 5
Results of the logit regressions used for picking the client and deal characteristics and other test statistics

	Univariate logit	Multivariate logit
Predictor variable / Explanatory variables	*Default (1=default; 0=performing)*	*Default (1=default; 0=performing)*
szla_ltv (ltv at disbursement)	0.85152*** (0.0106)	1.20208*** (0.0136)
ugyf_iskveg (education)	–0.51747*** (0.0041)	0*** –0.20131 (0.0098) –0.74801 (0.0108)
korosztaly (age cohort)	–0.47459*** (0.0076)	0*** –0.28976 (0.0078)
eltelt_ido (time from disbursement)	–0.00705*** (0.0001)	–0.00870*** (0.0001)
adostars (co-debtor)	–0.21042*** (0.0042)	0*** –0.22223 (0.0043)
szla_futamido (repayment period)	0.00240*** (0.0000)	0.00305*** (0.0000)
pti_felv (pti at disbursement)	0.82692*** (0.0077)	0.55789*** (0.0074)
termek (loan type)	0.60353*** (0.0042)	0*** 0.90221 (0.0052)
szla_deviza (currency)	1.12028*** (0.0085)	0*** 0.79321 (0.0087)
hitelossz_kereset (inflation adjusted loan amount)	0.02188*** (0.0002)	0.01036*** (0.0003)
vintage	–0.05582*** (0.0010)	
d_szla_kamat (interest rate)	5.48997*** (0.3872)	
	VIF	**1/VIF**
szla_ltv (ltv at disbursement)	9.57	0.1045
ugyf_iskveg (education)	0 11.82 6.33	0 0.0846 0.1581
korosztaly (age cohort)	0 13.63	0 0.0734
eltelt_ido (time from disbursement)	3.17	0.3151
adostars (co-debtor)	0 2.66	0 0.3755
szla_futamido (repayment period)	11.80	0.0848
pti_felv (pti at disbursement)	4.84	0.2065
termek (loan type)	0 2.42	0 0.4133
szla_deviza (currency)	0 6.56	0 0.1525
hitelossz_kereset (inflation adjusted loan amount)	4.60	0.2174
Average VIF	7.04	

*Note: *p<0.1; **p<0.05; ***p<0.01. Standard errors are shown in brackets. In the case of the category variables, the one taking the value of 1 is the basis, and the PD of the rest is compared to that.*

Figure 5
The ROC curve of the logit regression



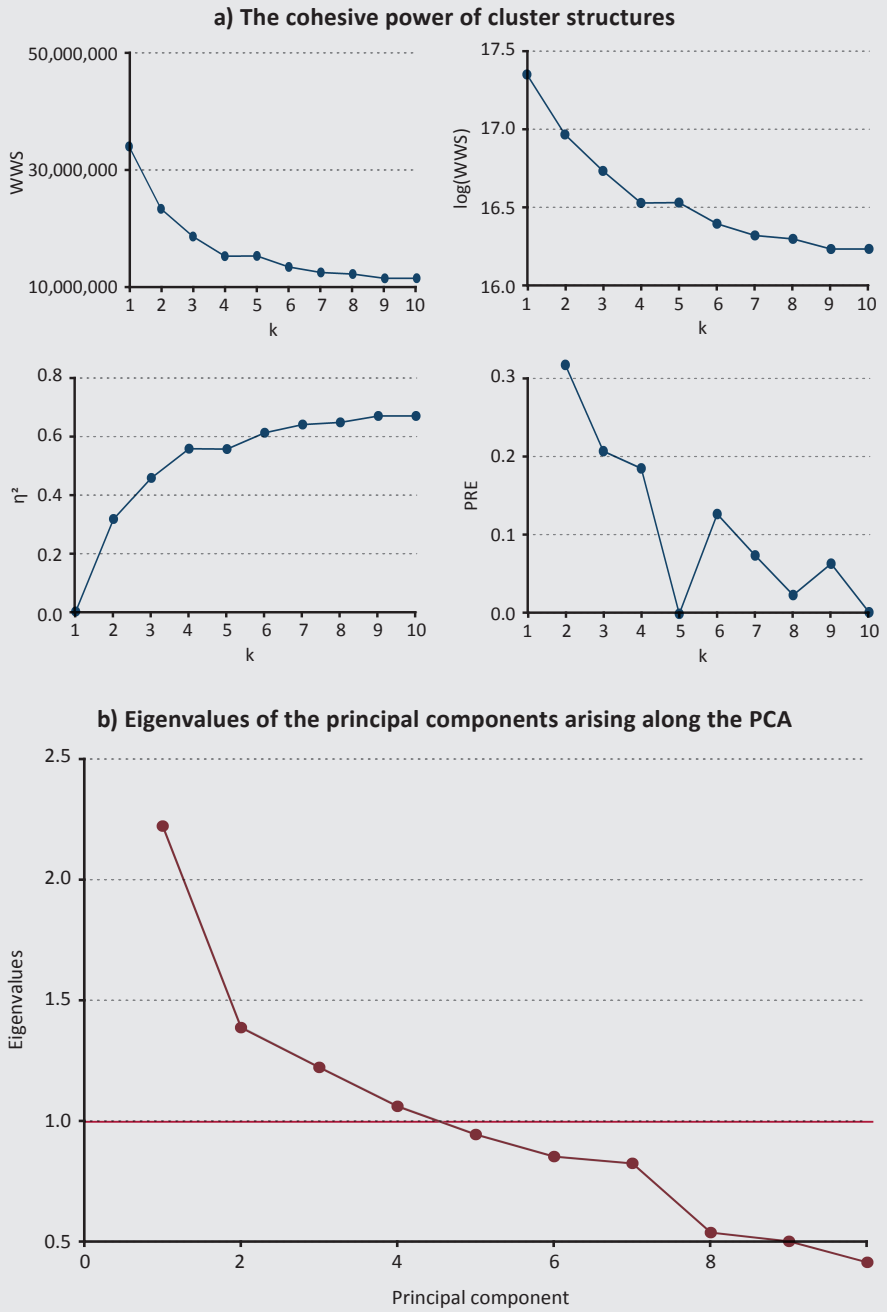
Note: In a perfect model, the area under the ROC curve is 1. In a simple random model, the area under the ROC curve is 0.5.

Table 6
Statistics and figures of the PCA and *k*-means cluster analysis

	PC1	PC2	PC3	PC4
szla_ltv (ltv at disbursement)	0.5100	–0.0577	0.0110	0.0918
ugyf_iskveg (education)	0.1646	–0.4606	0.1207	0.0835
korosztaly (age cohort)	–0.1102	–0.0608	0.4031	0.6107
eltelt_ido (time from disbursement)	0.0504	0.3255	–0.4959	0.4856
adostars (co-debtor)	–0.0778	0.1885	0.4448	0.4671
szla_futamido (repayment period)	0.4971	0.0594	–0.1819	0.1111
pti_felv (pti at disbursement)	0.1601	0.4773	0.4086	–0.3275
termek (loan type)	–0.4230	0.3105	0.1090	–0.1410
szla_deviza (currency)	0.1164	0.5443	–0.1918	0.0771
hitelossz_kereset (inflation adjusted loan amount)	0.4764	0.1236	0.3611	–0.1109

Note: 'PC' denotes the established principal components, while the values show the explanatory variables' coefficients in the different principal components.

Figure 6
Figures of the PCA and the *k*-means cluster analysis



Note: The cohesive power of the different cluster structures is measured along WSS (within sum of squares), η^2 and PRE (the percentage drop in the WSS).

Table 7
Correlation matrix of the explanatory variables used for the time series analysis

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
(1)	d_infl	1.0000														
(2)	d_buxvola	–0.0004	1.0000													
(3)	d_bux	0.2952	–0.0877	1.0000												
(4)	d_bub3m	0.0810	0.0635	–0.4726	1.0000											
(5)	d_eurib3m	0.0734	0.0720	0.2457	0.0293	1.0000										
(6)	d_gov10y	–0.0410	0.0000	–0.4501	–0.0152	–0.2682	1.0000									
(7)	d_wealth	0.3231	–0.1070	0.6185	–0.1611	0.2650	–0.6026	1.0000								
(8)	d_eurhuf	–0.3043	0.0029	–0.5902	0.1138	–0.4678	0.6116	–0.4498	1.0000							
(9)	d_hinc	–0.2171	–0.0803	–0.1870	–0.0234	0.1020	–0.0901	0.0308	0.1205	1.0000						
(10)	d_wage	0.1661	–0.0769	0.1080	0.3364	0.1063	–0.1876	0.2527	–0.1072	–0.1297	1.0000					
(11)	d_emp	–0.0409	0.2646	–0.0656	0.0123	0.3273	0.0349	0.1307	–0.0076	0.3078	0.0996	1.0000				
(12)	d_imp	0.2304	–0.1627	0.4284	–0.2343	0.5885	–0.2115	0.3278	–0.3333	–0.0223	0.2057	0.1302	1.0000			
(13)	d_exp	0.2054	–0.0292	0.3170	–0.1755	0.5531	–0.1249	0.2677	–0.2142	0.0060	0.1950	0.1990	0.8694	1.0000		
(14)	d_gdp	0.0658	–0.1337	0.2483	–0.3437	0.4642	–0.2040	0.2963	–0.2195	0.1080	0.1499	0.1923	0.6172	0.6355	1.0000	
(15)	d_unemp	0.0057	–0.0594	–0.0524	0.0495	–0.3801	0.1158	–0.0462	0.2026	–0.3743	0.3026	–0.4708	–0.2308	–0.1605	–0.0572	1.0000

Note: The table includes the correlation coefficients between the (potential) time series explanatory variables.

Figure 7
Clusters' time series PDs and averages

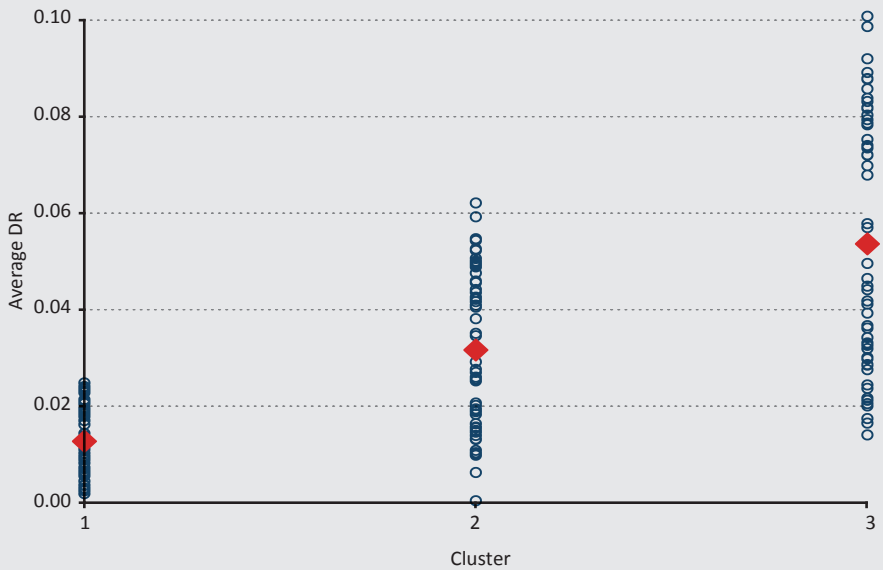


Table 8
Results of the stationarity tests

d_DR_y	–3.328	d_eurhuf	–6.332
d_infl	–6.140	d_hinc	–8.101
d_buxvola	–10.81	d_wage	–8.637
d_bux	–4.816	d_emp	–4.938
d_bub3m	–4.965	d_imp	–5.363
d_eurib3m	–3.554	d_exp	–5.412
d_gov10y	–8.130	d_gdp	–5.207
d_wealth	–6.066	d_unemp	–7.739

Note: The critical value is –3.576 at 1 per cent, –2.928 at 5 per cent, and –2.599 at 10 per cent.

Table 9
Results of the time series regression tests by clusters

	Clusters		
	1	**2**	**3**
Predictor variable / Tests	*d_DR_y*	*d_DR_y*	*d_DR_y*
Breusch-Pagan / Cook-Weisberg test (heteroscedasticity)	2.13 (0.1443)	3.72 (0.0537)	0.01 (0.9137)
Durbin-Watson alternative test (autocorrelation)	0.92 (0.3383)	0.22 (0.6377)	0.12 (0.7341)
Ramsey RESET test (excluded variable)	0.97 (0.4167)	2.49 (0.0764)	1.34 (0.2756)
Wu-Hausman F-test (endogeneity)		0.46 (0.4994)	

Note: The p-value is shown in brackets.

Table 10
Results of the multicollinearity time series regression tests by clusters

	Clusters		
	1	**2**	**3**
Predictor variable / Explanatory variables	**VIF**	**VIF**	**VIF**
d_emp	1.14	1.02	1.02
d_exp	1.09		
l1_d_gdp	1.10		
d_gov10y	1.02		
d_bub3m	1.03	1.33	1.04
d_wealth		1.06	1.06
l3_d_gov1y		1.06	
l1_d_bux		1.27	
l3_d_hinc			1.02
Average VIF	**1.08**	**1.15**	**1.03**

Table 11
Robustness analysis with three approaches (cross-sectional, time series truncation, exclusion of variables)

	Clusters		
	1	2	3
Predictor variable / Explanatory variables	*d_DR_y*	*d_DR_y*	*d_DR_y*
cross-sectional validation (25%)			
d_emp	–0.09887** (0.0413)	–0.17727*** (0.0651)	–0.25181*** (0.0886)
d_exp	–0.01866* (0.0107)		
l1_d_gdp	–0.00029 (0.0002)		
d_gov10y	0.00051* (0.0003)		
d_bub3m	0.00128** (0.0005)	0.00223** (0.0010)	0.00472*** (0.0012)
d_wealth		–0.04133** (0.0237)	–0.09045** (0.0323)
l3_d_gov1y		0.00101 (0.0007)	
l1_d_bux		–0.01005* (0.0058)	
l3_d_hinc			–0.09309** (0.0330)
time series validation (2007Q2–2014Q1)			
d_emp	–0.03989 (0.0340)	–0.17727* (0.0796)	–0.27969** (0.1078)
d_exp	–0.01786* (0.0107)		
l1_d_gdp	–0.00041** (0.0002)		
d_gov10y	0.00044* (0.0003)		
d_bub3m	0.00136** (0.0004)	0.00223** (0.0008)	0.00546*** (0.0015)
d_wealth		–0.04133* (0.0296)	–0.08887** (0.0398)
l3_d_gov1y		0.00101** (0.0013)	
l1_d_bux		–0.01005 (0.0071)	
l3_d_hinc			–0.12337** (0.0477)
exclusion of variables (1: d_emp, 2: d_wealth, 3: d_wealth)			
d_emp		—0.16524** (0.0650)	–0.31230*** (0.0935)
d_exp	–0.01906*** (0.0068)		
l1_d_gdp	–0.00035*** (0.0001)		
d_gov10y	0.00042** (0.0002)		
d_bub3m	0.00141*** (0.0003)	0.00251** (0.0010)	0.00602*** (0.0012)
d_wealth			
l3_d_gov1y		0.00193*** (0.0007)	
l1_d_bux		–0.01192** (0.0058)	
l3_d_hinc			–0.09476*** (0.0348)

Table 11
Robustness analysis with three approaches (cross-sectional, time series truncation, exclusion of variables)

	Clusters		
	1	2	3
Predictor variable / Explanatory variables	*d_DR_y*	*d_DR_y*	*d_DR_y*
exclusion of variables (1: d_exp, 2: d_emp, 3: d_emp)			
d_emp	–0.0661** (0.0267)		
d_exp			
l1_d_gdp	–0.0003** (0.0001)		
d_gov10y	0.0005** (0.0002)		
d_bub3m	0.0016*** (0.0003)	0.0021** (0.0010)	0.0053*** (0.0013)
d_wealth		–0.0600** (0.0237)	–0.0946** (0.0355)
l3_d_gov1y		0.0020*** (0.0007)	
l1_d_bux		–0.0109* (0.0058)	
l3_d_hinc			–0.0825** (0.0365)
exclusion of variables (1: l1_d_gdp, 2: l3_d_gov1y, 3: d_bub3m)			
d_emp	–0.0672*** (0.0262)	–0.1582** (0.0690)	–0.2646** (0.1086)
d_exp	–0.0190** (0.0069)		
l1_d_gdp			
d_gov10y	0.0005*** (0.0002)		
d_bub3m	0.0016** (0.0003)	0.0028*** (0.0010)	
d_wealth		–0.0546** (0.0252)	–0.1086*** (0.0391)
l3_d_gov1y			
l1_d_bux		–0.0073 (0.0058)	
l3_d_hinc			–0.0707* (0.0403)
exclusion of variables (1: d_gov10y, 2: d_bub3m, 3: l3_d_rendjov)			
d_emp	–0.0497* (0.0270)	–0.1374** (0.0656)	–0.2872*** (0.0925)
d_exp	–0.0182** (0.0069)		
l1_d_gdp	–0.0003** (0.0001)		
d_gov10y			
d_bub3m	0.0014*** (0.0003)		0.0054** (0.0012)
d_wealth		–0.0592** (0.0238)	–0.0891*** (0.0334)
l3_d_gov1y		0.0023*** (0.0007)	
l1_d_bux		–0.0161*** (0.0053)	
l3_d_hinc			

Table 11
Robustness analysis with three approaches (cross-sectional, time series truncation, exclusion of variables)

	Clusters		
	1	**2**	**3**
Predictor variable / Explanatory variables	*d_DR_y*	*d_DR_y*	*d_DR_y*
exclusion of variables (1: d_bub3m, 2: l_d_bux, 3: -)			
d_emp	–0.0461 (0.0307)	–0.1540** (0.0637)	
d_exp	–0.0205** (0.0079)		
l1_d_gdp	–0.0003** (0.0001)		
d_gov10y	0.0004* (0.0002)		
d_bub3m		0.0030*** (0.0009)	
d_wealth		–0.0591** (0.0231)	
l3_d_gov1y		0.0018*** (0.0007)	
l1_d_bux			
l3_d_hinc			

*Note: *p<0.1; **p<0.05; ***p<0.01. Standard errors are shown in brackets. 'd' is the annual change in the variable, 'l' is the quarterly lag, while 'y' indicates the annual nature of the probability of default.*

Transition of Hungarian Companies to IFRS-based Reporting in Relation to Indicators Used in Credit Approval*

Eleonóra Tarpataki – Janka Filyó – Norbert László

Legal requirements and opportunities are prompting more and more Hungarian companies to prepare their financial statements in accordance with International Financial Reporting Standards (IFRS). In our study, we examine the impact of transition using typical indicators that are frequently included in financial institutions' rating criteria. We compared the balance sheet, P/L account and cash flow data of 42 companies operating in different industries, as reported in their statements prepared in accordance with Hungarian and international regulations, and concluded that although there may be significant variations at an individual level, this is not the case in terms of the median of the aggregate data. Although the introduction of the European Single Electronic Format (ESEF), which allows for uniform interpretation and automatic processing of financial statements, has also been postponed for one year in Hungary due to the pandemic, it will open new perspectives for the development of rating systems, requiring preparations by credit institutions.

Journal of Economic Literature (JEL) codes: M41, G21, G32, C21

Keywords: IFRS transition, rating, indicators, ESEF

1. Introduction

Globalisation can be observed in many areas of the economy, including accounting. One of the most readily apparent signs of this is the spread of International Financial Reporting Standards (IFRS), which are becoming mandatory, or respectively optional in more and more countries. Based on data from the International Accounting Standards Board (IASB), the use of IFRS is currently possible in 144 countries around the world (*IFRS 2018*; *Madarasiné Szirmai – Szöllősiné Szép 2018*).

* The papers in this issue contain the views of the authors which are not necessarily the same as the official views of the Magyar Nemzeti Bank.

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One significant milestone in this spread was the requirement, starting from 2005, for listed corporate groups in the European Union to publish their consolidated accounts on the basis of IFRS (optional for non-listed companies). In Hungary, however, in terms of individual accounts, the transition was not to occur for another decade. IFRS reporting obligations were imposed on listed companies (typically parent companies) from 2017, and then on credit institutions from 2018 (they could start one year earlier at their discretion). Apart from these entities, large enterprises (subject to audit obligations) are given the choice between the Hungarian Accounting Act and IFRS. Below this size, the transition to international accounting is currently not possible.

Research carried out during this period assessed from the perspective of businesses the most common reasons for the transition, as well as the aversions, arguments and opinions that discourage decision-makers from taking the step. Most businesses are driven to make the transition by parent company expectations and legal requirements (*Deloitte 2018*), while others seek to increase the trust of their foreign partners or future investors by preparing financial statements in accordance with international standards. While a few years ago concerns over having enough professionals to carry out the transition and the IFRS accounting work were justified, the latest data show that a considerable proportion of both chartered accountants and auditors now hold IFRS certifications and are able to meet the needs of the corporate sector in this regard.[1]

The first transition opportunity opened up in 2016 for individual accounts, followed by the mandatory rounds in 2017 and 2018 for the companies mentioned above. However, several other companies have also made a voluntary transition to IFRS. Currently, this group comprises hundreds of companies, providing a sample size that allows for a statistical analysis of the effect of transition. Analysis is also facilitated by the fact that in the year of the transition, accounts under the new rules (IFRS) must be drawn up for both for the year concerned and, to provide comparative data, for the base period, affording comparisons with the reference period of the accounts drawn up according to the old rules (i.e. the Hungarian Accounting Act). Thus, companies disclosed their accounts for the same period – the business year preceding the transition – according to both sets of rules, and therefore any variations can only be attributed to the transition. An additional source of information is the Notes to the first IFRS accounts, which also explains values obtained as a result of the switch between accounting systems (*Lakatos et al. 2018*).

The number of transitioning companies is sufficient for a general, aggregated analysis, but still insufficient for the analysis to be conducted on a stratified, e.g. industry-specific basis.

[1] According to the latest data, 4.3 per cent (2,322) of the more than 53,000 chartered accountants in the Ministry of Finance register and about 6.4 per cent (262) of active auditors have IFRS certifications. See: https://penzugyiszakkepzes.kormany.hu/nevjegyzek-konyvviteli-szolgaltatast-vegzok. Downloaded: 10 May 2021.

2. Database

Unfortunately, there is no publicly accessible database of companies transitioning to IFRS, which therefore had to be built in the first step of our research. Based on consultations with experts, we formulated an initial assumption for identifying companies that have already transitioned to IFRS. We would like to thank everyone involved for their cooperation. 123 enterprises were included in the raw database, which had to be cleaned up for analysis in several respects. In the first instance, we removed companies (21) that, according to their individual accounts, had not yet migrated to IFRS at the time of analysis, and are only expected to do so later. For some of these, the consolidated accounts are already prepared on an IFRS basis, but the individual accounts of the enterprise operating as a member of the group are not. We were surprised to find several companies in Hungary with only IFRS accounts, which had not transitioned from Hungarian accounting standards. This is explained by the fact that they had recently been established, applying IFRS from the outset. Given the focus of our research on transition, we also had to remove this set from the database (15 companies). After the first round of qualification, we had a population of 87 entities with meaningful transition, i.e., accounts under both the Accounting Act and IFRS available for the year preceding the transition. The second round involved another two steps of cleaning. We removed 4 companies with special status (e.g. pre-companies, companies in bankruptcy proceedings), because we sought to focus our research on companies with continuous operations. The last round of qualification was based on the activity of the company. Seeking to restrict our analysis to companies that draw up their annual accounts according to the Accounting Act using the balance sheet and P/L account templates provided in its annexes, from the cases to be processed we eliminated companies using templates based on various government regulations (e.g. financial institutions, insurers). The latter step represented the most extensive qualification, eliminating 40 items from our database, but, as our research seeks to examine the impact of the transition in relation to the indicators used in the credit approval process for companies, the step was justified in that regard. After the filtering above, 42 companies remained eligible for analysis. While this is a relatively small set, it is significant when compared to the number of companies that have transitioned and do not pursue special activities.

As far as the year of transition is concerned, of the companies concerned, three of the companies made the transition in 2016, thirty in 2017, and nine in 2018. Although there were a significant number of transitioning companies in 2018 as well, this included many credit institutions meeting their transition obligations, which fell outside the target group of our research.

Examining the entities in our analysis by main activity, we found high diversity in terms of NACE Rev. 2, with no outstanding item numbers in any category. The companies are classified in the three major categories of activity as follows: industry 26 per cent, trade 17 per cent, and services 57 per cent.

3. Identification and analysis of variations in balance sheet and P/L account data

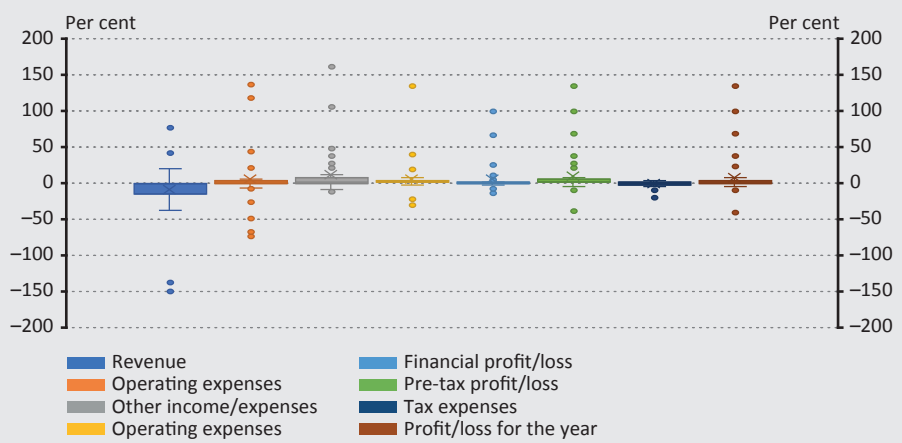
Our analysis started with a structural examination of the main statements of the accounts (balance sheet, profit and loss account), where we explored whether the transition caused any significant changes in the main categories of these two statements. Given the differences of magnitude in the size of the companies, instead of absolute figures we examined relative values, for which our benchmark was the equity figure as reported in the accounts of the companies drawn up in accordance with the Hungarian Accounting Act.

When processing the collected data, we also prepared two box plots (*Figures 1* and *2*), as well as a table presenting averages, standard deviations and quartiles (*Table 1*). However, due to space limitations, the results obtained are presented in such detail only in the first case, for the main categories of the P/L account. In the rest of our paper, the values obtained are illustrated by means of "squeezed" box plots with outliers removed.

3.1. Profit and loss statement

Figure 1 shows the changes in the main categories of the profit and loss account attributable to the transition.

Figure 1
Changes in main P/L account categories



Source: Calculation and editing based on the accounts of the sampled companies

As interpretability is hindered by outliers attributable to a few special cases, *Table 1* also includes quartiles in addition to averages and the standard deviations.

Table 1
Changes in main P/L account categories (details)

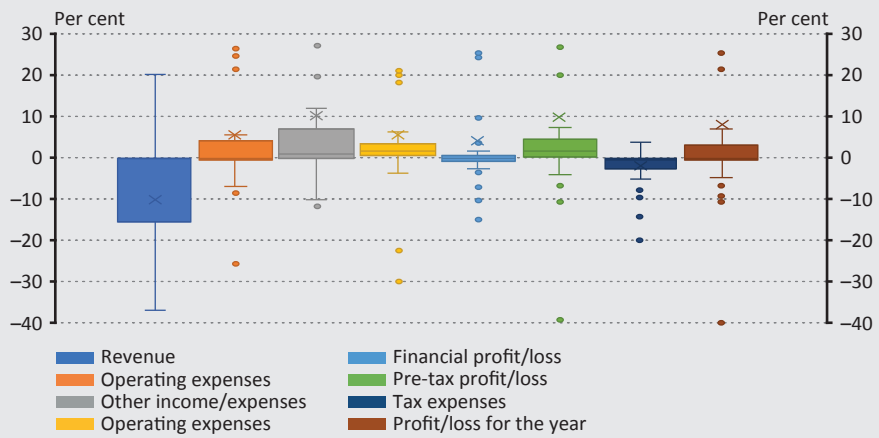
	Revenue	Operating expenses*	Other income	Operating profit/loss	Financial profit/loss	Pre-tax profit/loss	Tax expenses	Profit for the year
Average	*–10.1%*	*5.5%*	*10.3%*	*5.7%*	*4.2%*	*9.9%*	*–1.9%*	*8.0%*
Standard deviation	36.0%	35.3%	30.6%	22.6%	19.4%	28.7%	4.4%	28.9%
Q1	–14.1%	–0.3%	0.0%	0.5%	–0.6%	0.3%	–2.5%	–0.5%
Q2	0.0%	0.0%	0.9%	1.7%	0.0%	1.8%	–0.3%	0.0%
Q3	0.0%	3.7%	6.2%	3.4%	0.6%	4.4%	0.0%	2.3%

*Note: * Direct and indirect operating expense was derived from the total cost P/L account as follows: material expense + personnel expense + depreciation expense – own work capitalised.*

Source: Calculation and editing based on the accounts of the sampled companies

Based on this, it can be established that *significant differences attributable to the transition to IFRS occur only at a fraction of the companies*, and in many cases, these only affect the internal structure, i.e. they are transfers between two subcategories, and the *final result* – in this case the profit for the year – *is less affected overall*. *Figure 1* is therefore also shown with the outliers eliminated (*Figure 2*).

Figure 2
Changes in main P/L account categories without outliers



Source: Calculation and editing based on the accounts of the sampled companies

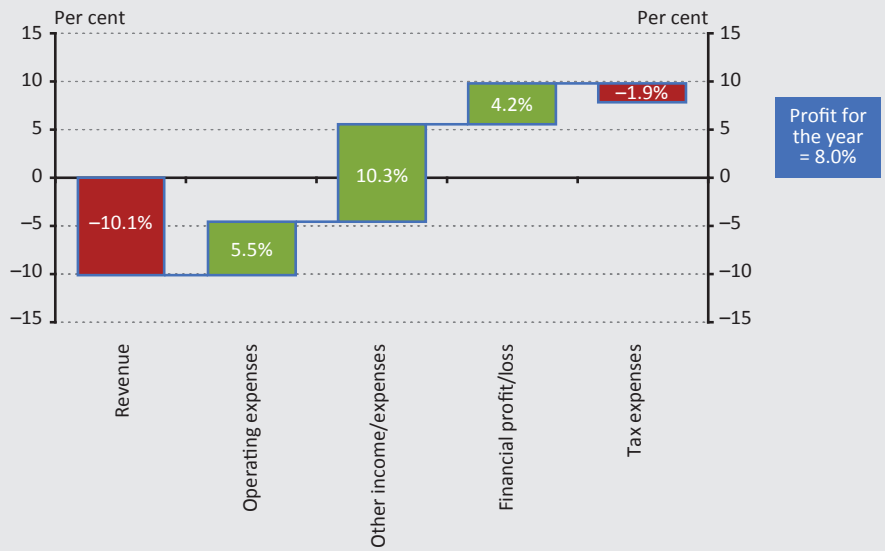
For a number of companies, the transition had no effect at all involving modification of the results. However, when the average differences are examined in terms of the highlighted lines, variations of different sizes can already be found. In IFRS accounts, the figures for revenues and for operating and other expenses decreased compared to the accounts prepared under the Hungarian Accounting Act. One of the main reasons for this is the netting requirement in IFRS, i.e. in a number of cases, revenues and expenses must be recognised in the aggregate. Such cases include, for example, the recognition of agency activities, where under Hungarian accounting standards consideration for sales is presented as revenue and consideration for purchases as expense, whereas IFRS requires the recognition of the difference between the two (agency commissions), resulting in a far lower revenue amount due to the elimination of expenses. A similar case involves the treatment of excise duty, which under Hungarian accounting standards is recognised in revenue to increase profit and in other expenses to decrease profit, whereas it is not recognised at all in profit under IFRS. Having said that, the effect of those two cases will disappear from the operating/business level onwards.

One of the reasons for variations in the financial result is that in IFRS transaction costs related to loans (e.g. disbursement fees) are not charged to profit or loss at the time of borrowing, but are used to adjust the cost of the liability, as a result of which it will become an expense over the tenor, due to the differential of effective and nominal interest rates.

With regard to tax expenses, two differences should be pointed out. One is that Hungarian accounting standards are only concerned with the actual income tax for the year, while under IFRS deferred tax also requires treatment. The other is the question of the treatment of the local business tax (HIPA), a Hungarian specialty. Under Hungarian accounting standards, that tax unambiguously belongs in other expenses, but there is no such requirement in IFRS, and depending on their interpretation, entities have a choice of two options. Under IFRS, the local business tax may either be presented among other expenses, but where interpreted by the company as an income tax, may also be presented as a tax expense. There is currently no established Hungarian practice in that regard, not even for listed companies. This optional classification could play an important role in the judgement of a management or a company, since the decision also affects calculated result categories such as EBIT or EBITDA.

Based on our analysis of our sample, we found *transition causing an average 8 per cent increase in profit for the year* (relative to equity), the aggregate effect of which in terms of the line items examined is shown in *Figure 3*.

Figure 3
Variables with an effect on profit for the year attributable to transition



Source: Calculation and editing based on the accounts of the sampled companies

This, however, can be traced back mainly to the outliers of a few enterprises, whereas a much smaller difference is obtained for the majority. There is no variation (0.0 per cent) in the median, and the interquartile range is also quite narrow, with values varying between –0.5 per cent and +2.3 per cent.

In the P/L account of the IFRS accounts, there are two other categories that differ significantly from the Hungarian regulations. One is other comprehensive income (OCI), which includes part of the fair value differences, separately from profit for the year. This will be transferred to equity at the end of the year. A similar solution is also available under Hungarian accounting standards, although in the latter these items are recognised directly in equity, and the scope of the assets and events concerned is also partly different. Given the absence of any direct effects on profit for the year in either accounting system, no detailed explanation will be given here. The other variation is related to the discontinued operations, an item that is disclosed separately only in IFRS accounts, while in the Hungarian version its P/L effects remain in the lines corresponding to its content, potentially causing a variation in virtually any lines within the P/L account. In the sample examined, 6 companies had other comprehensive income, and profit/loss from discontinued operations was separated in two cases, neither of which were significant.

In *Table 2*, we provide a summary of the common causes of individual variations and their effect on the indicators used in the analyses.

Table 2
Most common causes of individual variations in main P/L account categories

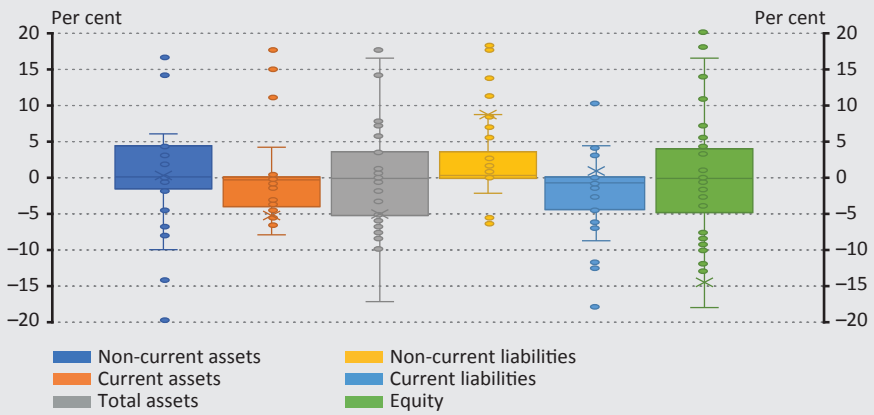
Economic event / key area	IFRS vs. Hungarian regulations	Hungarian P/L account items affected	Indicators influenced, with direction of effect
Agency activities	Revenue is disclosed in netted form under IFRS	Revenue, material expenses, operating expenses	Indicators related to revenue (increase due to lower base)
Excise duties	Not included in revenue under IFRS	Revenue, other expenses	Indicators related to revenue (increase due to lower base)
Local business tax	Recognised either as other expense or a tax expense under IFRS	Other expense, tax expense (chargeable tax under the Accounting Act)	Indicators based on EBIT/EBITDA (where recognised as a tax expense, indicators increase)
Discontinued operations	To be presented separately in IFRS	May affect any P/L account line	Indicators related to the P/L account (effect depending on P/L)
Depreciation	Depreciation as recognised under the IFRS leasing standard is absent in Hungarian regulations	Services contracted Depreciation	EBIT/EBITDA based indicators increase

Source: Editing based on the accounts of the sampled companies

3.2. Balance sheet

In the financial statements of the accounts, we then turned to the analysis of assets (balance sheet). In terms of the balance sheet, the fluctuations caused by transition were even smaller on average than in the case of the P/L account. Due to one or two extreme outliers, the resulting plot was even more “squeezed”. For easier interpretation, the middle of each plot was also magnified here, with extreme outliers eliminated (*Figure 4*).

Figure 4
Changes in the main components of the balance sheet due to transition to IFRS



Source: Calculation and editing based on the accounts of the sampled companies

For many companies, the transition to IFRS did not entail any changes in the figures reported for the key balance sheet items. However, structural shifts can also be observed here. The analysis was made more difficult by the fact that prepayments, as well as accruals and deferred income are included in the balance sheet under the Accounting Act as a separate main group, whereas under IFRS they are typically part of current assets and current liabilities. For our analysis, we also aggregated these items in the Hungarian version, as it was not possible to separate the IFRS data. Provisions are also a separate main group in the Hungarian balance sheet, while they are liabilities under IFRS. Here the problem is caused by the fact that although reclassification could be done easily, in our analysis we would like to examine non-current and current liabilities separately. As such a breakdown of provisions is absent in Hungarian accounts and only exists under IFRS, we could only examine the latter. In doing so, we found that half of the companies do not have any long-term provisions, and the figures are typically not significant in the other half either. Consequently, for both versions we considered provisions as being part of current liabilities. This leaves us with five large balance sheet categories: fixed assets, current assets, equity, non-current liabilities, and current liabilities.

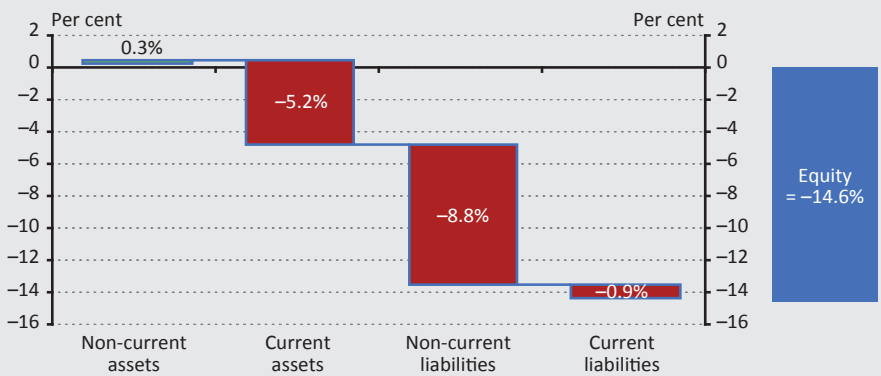
The smallest variation was found in relation to fixed assets, which may be explained by the fact that both accounting systems employ highly similar approaches in this area. Obviously, there are differences in the details, e.g. the capitalisation of establishment and reorganisation is only permitted under Hungarian accounting standards, whereas deferred tax assets are only included in the IFRS balance sheet. With current assets, the difference resulting from transition is already far greater, and the figures tend to be lower under IFRS. One of the reasons for this

is the treatment of repurchased own shares and participations. Pursuant to the Accounting Act, such items must be presented in the securities group of current assets, while under IFRS they are treated as items reducing equity from the moment of repurchase, and are thus completely disregarded in the statement of assets.

On the liability side, one major variation is due to the additional contributions paid. This is treated as equity (tied-up reserve) under Hungarian accounting standards, and as a liability under IFRS.

On both the asset and the liability side, variations may arise from different definitions of cost, for example because discounted cash flow approaches are used in IFRS, whereas there is no such approach in the Accounting Act. The effect of transition on changes in main balance sheet items is shown in *Figure 5* according to the impact on the company's equity, that is, we follow the Anglo-Saxon logic where assets – liabilities = equity, except that both assets and liabilities are subdivided into long and short items, i.e., in our equation fixed assets + current assets – non-current liabilities – current liabilities = equity.

Figure 5
Impact of transition to IFRS on main balance sheet items and equity



Source: Calculation and editing based on the accounts of the sampled companies

3.3. Cash flow

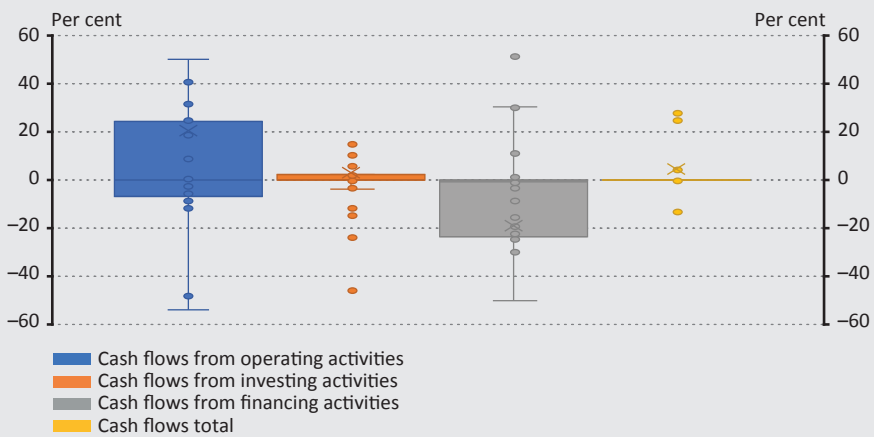
The cash flow statement is an essential element of the accounts, especially when it comes to credit assessment. It is included in both sets of accounts, but treated as having a different weight in each. Under IFRS, it is included as a main statement on an equal footing with the balance sheet and P/L account, while the Accounting Act requires it as part of the notes on the accounts. Unfortunately, this undervaluation is further exacerbated in practice, with many companies either failing to draw up a cash flow statement altogether (in contravention of the requirement), or relegating it to the last pages. The issue appeared in our database as well: for both

Hungarian and IFRS accounts, we found three companies each that failed to provide the mandatory cash flow statement. As a scrap of comfort, one entity was doubly "negligent" and thus only 5 cases had to be removed, leaving us with 37 companies for the purposes of subsequent analysis.

Regarding cash flow, one key question is what is meant by "cash" at all, i.e., what the basis of our statement will be, what we are looking for changes in. While the two accounting systems have different interpretations at the conceptual level, in the following we explore whether this is also reflected in practice. At 18 of the 37 companies, the value of the change in cash in the two systems is exactly the same, and in the remaining 14 cases the variation is not significant, leaving only 5 companies with any major difference. The value of IFRS cash may be higher due to cash equivalents and lower due to overdraft being construed as negative cash. However, this alone does not determine in which system the cash flow will be higher or lower; the change of the items referred to above in the given year should be taken into account.

An assessment of the values of the categories affecting the final cash flow result also points to structural shifts here. The changes are illustrated in *Figure 6*, again with the outliers eliminated.

Figure 6
Effect of transition to IFRS on cash flow categories

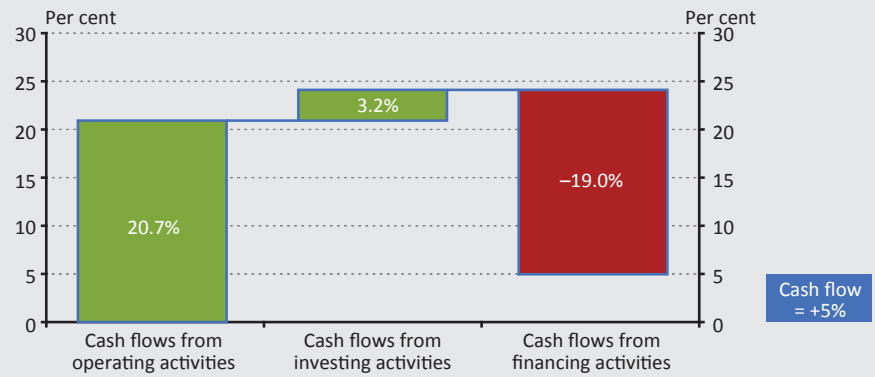


Source: Calculation and editing based on the accounts of the sampled companies

The main rearrangements between cash flow categories are due to the classification of paid returns (dividends, interest). The Hungarian regulations require both items to be classified in the operating category, while under IFRS the entity has the option to show such either as operating or financing cash flow. With nearly all entities, dividend paid is classified in the financing part; consequently, wherever an entity

has such an item, it can almost certainly be identified as a variation. By contrast, the practice is less uniform when it comes to interest. Accordingly, no difference between the two sets of rules will result from a company opting for the operating category, while opting for the financing category will make a difference. This is illustrated in *Figure 7*.

Figure 7
Changes in the main categories of cash flow due to transition to IFRS



Source: Calculation and editing based on the accounts of the sampled companies

4. Consequences of the transition with regard to indicators

The 2013 Act on Credit Institutions and Financial Enterprises requires financial institutions to develop and implement internal policies that allow for the "*soundness, transparency, risk assessment monitoring and mitigation of exposures and commitments*".[2] The 2016 MNB Decree on customer and counterparty rating provides a detailed description of what this internal policy should include. In Art. 5(e), this is specified as "*the definition of quantifiable data* […] *to be taken into account in the classification of customers and counterparties into rating categories, and the indicators used*".[3]

The rating system is based on credit rating models, which help in making credit decisions on the one hand and in the quantification of the probability of default on the other, by assigning borrowers (as well as loans) to risk categories in accordance with the lending policy. The models operate on the basis of historical data, i.e. they take into account previous lending experience, statistical and background data,

[2] See *Act CCXXXVII of 2013, Art. 98(1)*, Hungarian Legislation Database. https://njt.hu/jogszabaly/2013-237-00-00. Downloaded: 28 April 2021.
[3] See *MNB Decree 40/2016 (X. 11).*, Hungarian Legislation Database. https://njt.hu/jogszabaly/2016-40-20-2C. Downloaded: 28 April 2021.

the depth and reliability of which is one of the most important components of the models (*Walter 2019*; *Horváth 2021*; *Banai et al. 2016*).

A significant proportion of the input data of the rating systems includes factual and numerical data from the accounts and written statements by customers (e.g. questionnaire, supplementary data sheet), from which different indicators are formed in the assessment process (*Lucas et al. 2006*). The customer rating is used, on the one hand, to determine the fees and interest rate spreads, which affects revenues, and on the other hand to allocate provisions, which affects expenses, i.e., ultimately, the development of the indicators of the customers indirectly affects the profitability of the financial institution.

At this stage, in Hungary the transition to IFRS is characteristic of large corporates. These companies are individually assessed and rated by credit institutions for risk management purposes due to the larger exposures and more complex transactions involved. However, on the basis of the current regulations, medium-size and small enterprises can also opt to prepare IFRS-based accounts, which makes it appropriate, with the above considerations in mind, to carry out periodic reviews of whether the transition causes statistically significant changes in the functioning of the assessment models.

In our first survey, we selected the data required for the indicators examined only from the publicly available individual financial statements, focusing on the year of transition, with the following limitations in mind.

Hungarian accounts are in a fixed format, while IFRS do not prescribe a precise structure for the financial statements; or, if certain items are not significant in relation to the assessment of the company, they do not necessarily have to be presented separately in the numerical part of the statements. Consequently, in a number of cases we had to omit items about which the Hungarian accounts contain data, but in the IFRS-based financial statements we either did not find information, or only very rarely.

In the Hungarian balance sheet, at the level of detail for financial fixed assets, receivables and various payables, items outstanding with related entities, entities with a participating interest and entities with other shareholdings must be presented on separate lines, so that the business content (accounts payable/receivable, loan receivables/payables) of those items are overridden by this form of presentation. Therefore, the data of Hungarian balance sheet receivables/payables (from the supply of goods and services) can be significantly distorted, where e.g. intra-group sales typically occur.

Since our study specifically focused on a comparison of the values of the indicators obtained from Hungarian accounts data with the values obtained from the IFRS

financial statement for the same period, we did not include trend-like indicators in our analysis.

The possibilities of our survey were also influenced by the fact that for many indicators used in banks' risk analysis and rating processes, the input data are not publicly available at all, only included in the detailed corporate data requested before the lending relationship is established.

Table 3 provides a summary of the indicators that were examined in the light of the above, using the following data:

- From the P/L account directly: revenue, depreciation, operating profit/loss, interest expense; indirectly (calculated): EBIT, EBITDA
- From the balance sheet: fixed assets, current assets, total assets, equity, total liabilities, current liabilities

Table 3
Indicators examined and their calculation

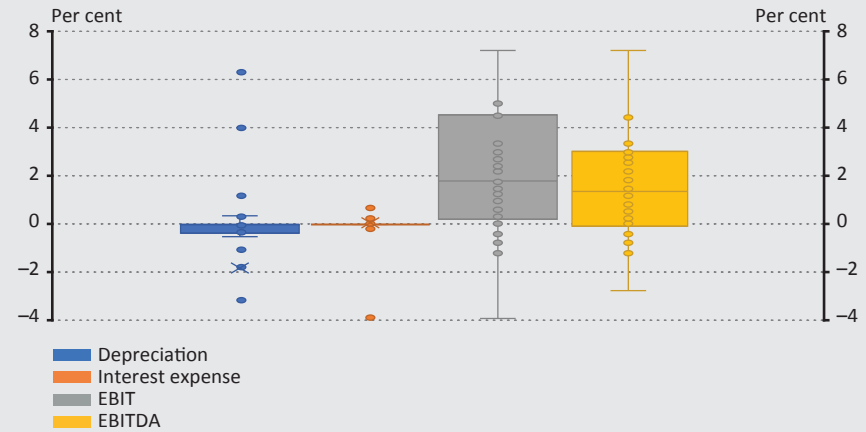
Profit on sales	Profit for the year / Revenue
EBIT rate	EBIT / Revenue
EBITDA rate	EBITDA / Revenue
Current ratio	Current assets / Short term liabilities (current liabilities)
Capitalisation rate	Equity / Balance sheet total
Liabilities to EBITDA	Liabilities / EBITDA

Before reviewing the changes in the above indicators as a result of the transition, let us also look at *Figure 8*, in which the depreciation and interest expense data and the changes in the EBIT and EBITDA values, two key P/L categories for bank ratings, are presented.

In the case of interest expense, the variation is insignificant; the explanation for the two outliers of depreciation is that while according to the Hungarian regulations, in the case of operating leases, the assets are not included in the books of the lessee and no depreciation (and interest expense) is accounted for, in many cases these transactions were classified as financial leases in accordance with IAS 17. Since then, the leases standard has been renewed and IFRS 16 has been in force as of 2019, which is expected to reinforce this difference.[4] Significant changes in the EBIT and EBITDA P/L categories are justified by this and the changes in the previously examined components.

[4] IFRS 16 Leases entered into force on 1 January 2019, with earlier application permitted in certain circumstances (*IFRS 2021*).

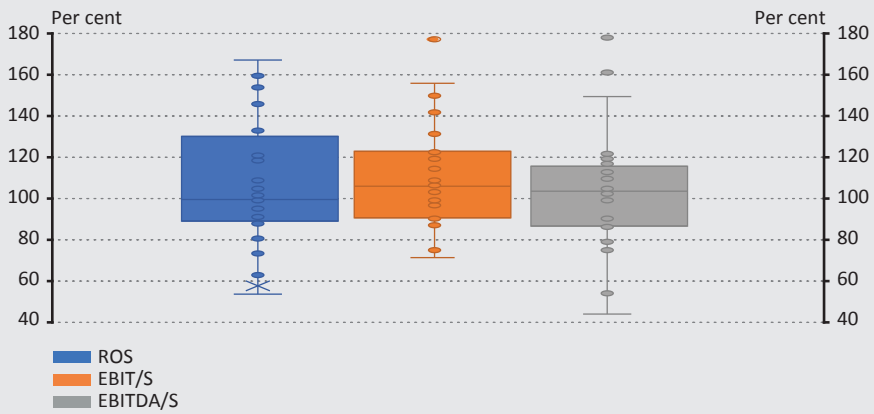
Figure 8
Depreciation, interest expense, changes in EBIT and EBITDA excluding outliers



Source: Calculation and editing based on the accounts of the sampled companies

Of the 42 companies selected for analysis, only 40 could be analysed in terms of revenue-based indicators, given the absence of revenue in two cases. Based on an overview of the figures and changes of return on sales (ROS), EBIT/S and EBITDA/S, we found that the higher value of the indicators was mainly due to the lower revenue in IFRS-based financial statements (*Figure 9*). The common reasons for this were discussed in detail in the previous chapter.

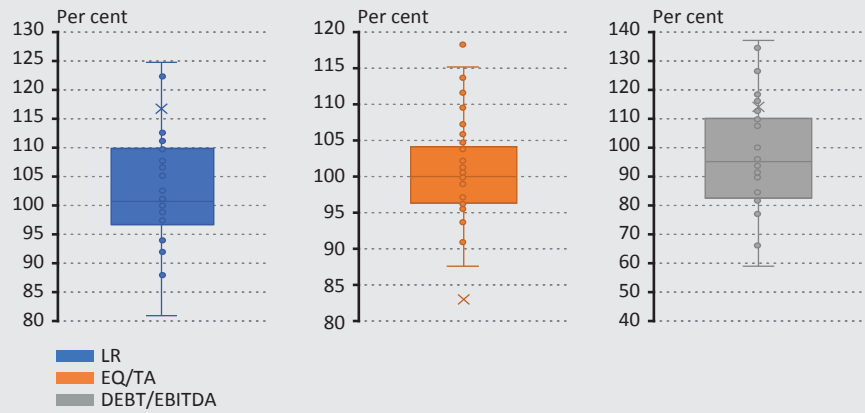
Figure 9
Change in the profit on sales, the EBIT rate and the EBITDA rate



Source: Calculation and editing based on the accounts of the sampled companies

Minimal variations were also obtained in terms of liquidity ratio (LR) and capitalisation ratios. The effect of changes in these indicators is illustrated in *Figure 10*. Instead of the average, which can be strongly distorted by the outliers, the median is also worth considering. For example, while the average variation of equity (E) is –14.6 per cent, in the case of the median it is 0 per cent; similarly, in the case of the balance sheet total (BST), these values are: –1 per cent (average) and 0 per cent (median).

Figure 10
Liquidity ratio (LR), capitalisation ratio (E/BST) and liabilities to EBITDA (DEBT/EBITDA)



Source: Calculation and editing based on the accounts of the sampled companies

What could be the key to a uniform interpretation of the financial statements and to providing for more data analysis and comparability? According to XBRL International, some type of financial reporting system based on XBRL (eXtensible Business Reporting Language) is already in use in more than 50 countries (*XBRL 2021*). For supervisors, tax authorities, investors and countless stakeholders alike, this provides simple and inexpensive opportunities for data collection.[5] In the United States, the SEC (Securities and Exchange Commission) has required listed companies to disclose their financial data on an XBRL basis since 2009 (*Singerová 2015*; *Liu et al. 2017*).

The new electronic reporting format, the European Single Electronic Format (ESEF), which has been developed by the European Securities and Markets Authority (ESMA) and is also based on XBRL, will be mandatory for companies whose

[5] One example is Magyar Nemzeti Bank itself in its supervisory capacity for credit institutions, requiring XBRL data reporting to be submitted to the European Banking Authority (EBA), with implementation originally scheduled for April 2020, postponed until October 2020 due to Covid-19.

securities are listed on any stock exchange in the European Union. The primary elements of the financial statements (balance sheet, comprehensive P/L account, statement of changes in equity, cash flow statement) should have been disclosed for the first time in 2020, but due to the pandemic, countries were offered the option for implementation in 2021 (Hungary also opted for postponement pursuant to *Government Decree No 1078/2021.* (*II. 27.*)). However, the items in the notes to the accounts for the financial years 2022 and onwards must also be labelled accordingly.

5. Summary and outlook

Based on our research, we concluded that the transition to IFRS did not affect the main figures in the financial statements of most of the sampled companies. (In many cases, the median of the variation is around zero, and the interquartile range is also very narrow.) However, with some companies there have been specific and marked variations (in many cases due to one or two types of events), so after the primary analysis, it is worth reviewing whether the company has assets and transactions that have been treated differently in Hungarian accounting and in accordance with international standards (typical examples have been presented in the previous sections).

The question remains whether the new format will help improve the position of lending banks. Listed companies will disclose their consolidated financial statements in this form; however, banks and financial institutions will have to provide ratings on the basis of individual accounts if they do not receive parent company guarantee cover for the loans of the subsidiaries. Thus, some of the statements that can be interpreted by machine reading and can be analysed later even by artificial intelligence can be used to improve rating systems and increase comparability (also internationally), but we cannot expect individual analysis, evaluation and database building to be "cut out" at the level of individual statements for a long time to come.

In another approach, however, there is a strong potential for disclosure in new electronic formats: after a reasonable period of time, it will provide all stakeholders with a comprehensive and searchable database, which will also provide an opportunity for modelling, exploring deeper connections and further innovation.

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Measuring the Climate Risk Exposure of Financial Assets – Methodological Challenges and Central Bank Practices*

Pál Péter Kolozsi – Sándor Ladányi – András Straubinger

In order to understand climate-related risks and opportunities, the availability and transparency of reliable financial information is essential. In this regard, the financial sector plays a special role owing to its ties to other economic sectors, and the exposure of financial institutions highlights the responsibility of central banks. This paper uses the literature related to environmental sustainability reporting as well as practical experience to describe the challenges encountered in assessing the green risks of financial assets (absence and heterogeneity of data, differences in definitions and requirements, lack of a uniform methodology, limits of rating schemes) and also details the climate risk measurement methodologies and practical solutions employed by central banks publishing their own climate-related financial disclosures, i.e. the Bank of England, the Banque de France and the Magyar Nemzeti Bank.

Journal of Economic Literature (JEL) codes: Q51, Q54, G32, E58

Keywords: climate change, transparency, TCFD recommendations, financial disclosure

1. Introduction

According to a report by the Intergovernmental Panel on Climate Change from 2021 (*IPCC 2021*), an unprecedented climatic change is underway, as the atmosphere, oceans and landmasses are heating up due to human activities. The rate of sea level rise and permafrost thawing has increased, and there are more and more extreme weather events, with increasingly serious consequences. The impact of this may be especially complex (*Zöldy et al. 2022*), which is shown by the fact that – in analogy to Nassim Nicholas Taleb's black swan[1] – many refer to climate risks and the green transition in finance as a 'green swan' (*Bolton et al. 2020*).[2]

* The papers in this issue contain the views of the authors which are not necessarily the same as the official views of the Magyar Nemzeti Bank.

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[1] *Taleb* (*2007*)

[2] The BIS held a Green Swan Conference in June 2021, where Agustín Carstens delivered a speech on the importance of transparency and measuring and reporting risks, pointing out the development of metrics and stress tests (*Transparency and market integrity in green finance*. The Green Swan Conference, Basel, 2 June 2021. https://www.bis.org/speeches/sp210602.htm. Downloaded: 9 February 2022).

Mitigating and halting climate change requires enormous financial resources. According to a World Bank estimate, between 2015 and 2030, investment in infrastructure amounting to USD 90 trillion globally would be needed to achieve the climate objectives (*UN 2021*), while the OECD estimates that investments in the order of USD 6,900 billion are needed to meet the climate goals stipulated in the Paris Agreement (*OECD 2020*). Another telling piece of information is that the COP 26 climate summit held between 31 October and 13 November 2021 focused partly on financing the efforts against climate change.[3] Certain countries have already embarked on the path of green transition for their economies, and many companies are working to make their operations sustainable. However, this will not be sufficient to ensure the transition to a sustainable, green economic model, as governments and firms will also need to forge 'strategic partnership' with participants in the financial system (*Matolcsy 2021*).

One of the basic preconditions for the transition to green finance is knowing the climate exposure of individual economic entities and assets. This requires transparency, which is crucial for building trust,[4] while the risk of 'greenwashing'[5] remains high (*Alogoskoufis et al. 2021a*). The financial sector plays a special role in all of this, as banks and other financial service providers have ties to the entire economy via financial intermediation. In other words, the climate risks of the financial sector[6] reflect the climate risks of the economy as a whole, as the system is interconnected (*Kolozsi 2021*). The significance of the financial system is further boosted by the fact that the green transition of economic operations and switching to a net-zero economy requires that the financial system be able to finance an appropriate amount of green investments, but major changes are necessary for that (*Carney 2021*).

Transparency represents value added for society, and it highlights the importance and responsibility of central banks in the case of the financial system.[7] In recent

[3] *COP26 Reaches Consensus on Key Actions to Address Climate Change*. Press Release, United Nations Framework Convention on Climate Change (UNFCCC), 13 November 2021. https://unfccc.int/news/cop26-reaches-consensus-on-key-actions-to-address-climate-change. Downloaded: 9 February 2022.

[4] *Setting New Standards: An Interview with Julie Becker of the Luxembourg Stock Exchange*. State Street, November 2018. https://www.statestreet.com/ideas/articles/setting-new-standards.html. Downloaded: 9 February 2022.

[5] According to *Delmas – Burbano* (*2011*), greenwashing is defined as firm behaviour where companies engage in positive communication about environmental performance, while actually exhibiting poor environmental performance.

[6] *Eceiza et al.* (*2020*) argue that 15 per cent of European bank balance sheets may be affected by climate risks, but their extent is yet to be explored. The financial system is highly interconnected, and it follows from this that individual financial institutions alone cannot mitigate financial stability risks (*FSB 2020*). The financial sector has close ties to real economy actors, so the banking system is also exposed to considerable real economy risk: if such stakeholders suffer losses, their lending activity may decline, which may undermine economic growth (*Baranović et al. 2021*). Climate risk regulations not only entail higher costs but also an opportunity to explore the related risks more accurately (*Calice – Caruso 2021*), although this is significantly hampered by the lack of data (*FSB 2020*).

[7] For more on transparency and the development of green financial markets, see, for example: *Kahlenborn* (*2001*) and *Talbot* (*2017*).

decades, the social role and influence of central banks has received increasing attention (*Siklos 2017; Lentner – Kolozsi 2019*), and central banks have shifted towards more transparent operation the world over, in line with the principle of democratic accountability. Central bank transparency is also relevant when it comes to measuring climate risks, since the central bank – as a public institution – should be expected to explore climate risks on its balance sheet not only because such risks can lead to potential losses, but also because the central bank may affect the climate consciousness of the other players in the financial sector, foster the development of best practices in measuring climate risks and set an example for commercial banks as well (*Campiglio et al. 2018; Dicau – Volz 2021*).

2. Thesis questions and the analysis methods used

The practical manifestation of green transparency is the measurement and reporting of the climate risk exposure of financial assets. This paper presents the methodological challenges and practical solutions of the climate risk analysis of central bank balance sheets, which clearly shows the limits and opportunities of this novel analysis, and may be used as a point of reference for the balance sheet analysis of other players in the financial sector; thus, it has broader applicability than the relatively narrow realm of central banking.

The following issues were examined:

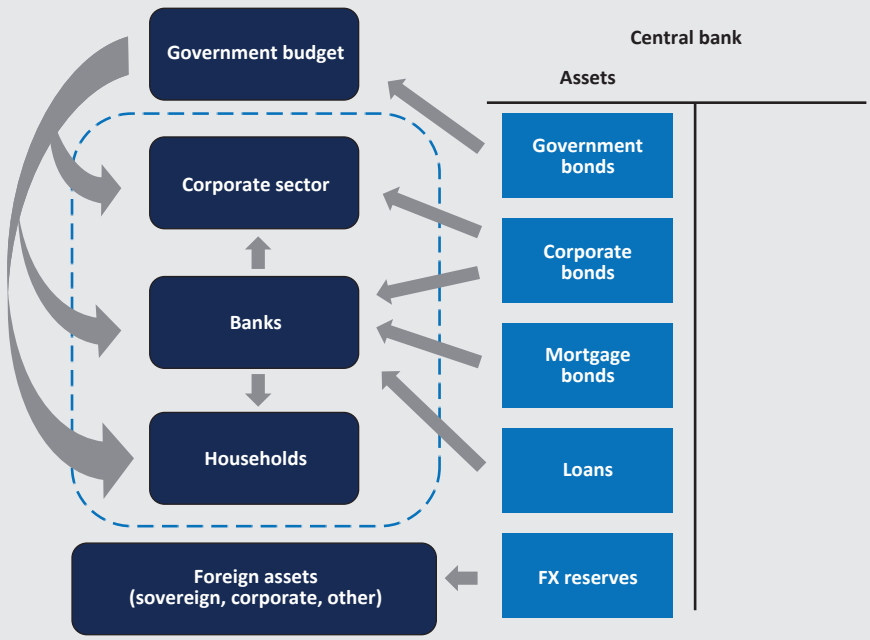
(1) Challenges that can be identified during the climate risk analysis of financial assets, in particular items that are relevant for central bank balance sheets.

(2) Practical solutions for addressing such challenges, as utilised by international recommendations and the central banks preparing climate-related financial disclosures.

This analysis focuses on assessing the exposure to climate risk of the relevant central bank balance sheet items and examines ways to report on financial account items in terms of climate risk, for whatever reason (e.g. regulatory requirements, demands by external stakeholders, personal commitment of executives). This means that the study does not cover the building of models that address the integration of climate considerations into financial decisions. Other aspects of sustainability (including the non-environmental facets of the ESG approach) are also not discussed here. Due to the nature of central bank balance sheets, the analysis covers a wide range of assets, as such balance sheets include SME and large enterprise loans, corporate and bank bonds as well as government securities, from not only domestic but possibly also foreign issuers. Due to the comprehensiveness objective, the analysis of the financial assets on central bank balance sheets has to cover the complete range of sectors and liabilities (*Figure 1*), even though such instruments may vary

widely in their nature and the applicable measurement framework, and thus can only be compared partially, with some limitations.[8]

Figure 1
Relationship between economic sectors and financial assets on central bank balance sheets



Exposure to climate risks, including the risks of financial institutions, can be divided into physical and transition risks, and this analysis covers both. *Physical risk* means that the change in climatic conditions, such as the rise and variability in average temperatures, a shift in the amount and distribution of precipitation, including droughts and floods, might affect the value of the financial assets on institutions' balance sheets. Physical risks come with a significant tail risk, i.e. low-probability events entailing large losses. The realisation of physical risks can suddenly and substantially reduce the price of the relevant assets, potentially leading to a shock, which in turn can have a destabilising effect in the entire financial system. Physical risks can be concentrated in certain industries or countries. *Transition risks* refer to situations when the value of financial assets changes in relation to the transition to a low-carbon economy. In the case of transition risks, faster-than-expected change in economic policy can cause a shock to the financial system.

[8] These include the differences between sovereign and corporate claims (government securities and corporate bonds).

The relative novelty of the thesis question and the issue called for special analysis methods. The examination was based on three main methodological pillars:

1) Review of the relevant literature, with a special focus on sources with experience in practical implementation (meta-analysis),

2) Description of international practices, in particular the climate-related financial disclosures produced by the Bank of England (BoE) and the Banque de France (BdF) as well as discussions with experts from these banks,

3) Experience gained from preparing the climate-related financial disclosure of the Magyar Nemzeti Bank (the central bank of Hungary, MNB) in 2022.[9]

3. Practical challenges in implementing climate risk transparency

When it comes to climate risks, the impact on bank balance sheets cannot be examined with the usual methods (*Baranović et al. 2021*), and measurement of the risks is all the more difficult because of the potential non-linear nature of the effects, and thus certain developments and events may entail larger losses than anticipated.

Based on the literature and the established practices, a summary of the most relevant challenges in measuring climate risk exposures is presented below. The challenges listed here arise not only in measuring climate risks for central banks, but also more universally, and they are also relevant for central banks' climate risk assessment due to the wide range of financial assets on central banks' balance sheets.

The measurement of climate risk exposure rests on the two pillars of data and methodology, and thus the challenges can also be identified in these two areas.

3.1. Data

3.1.1. The availability, amount and quality of data

Capturing climate risk exposure considerations requires high-quality, systematic and available input data (for investors and reporting entities alike), structured and processed by various models. According to the Basel recommendations (*BIS 2021*), climate risk as a risk factor can be categorised as a traditional risk (driver), so its

[9] The authors of this study helped prepare the MNB's climate-related financial disclosure as project leaders and experts.

impact can be translated into credit risk, market risk and liquidity risk,[10] but climate risk exposures can also be analysed and assessed outside these categories, 'in their own right'.

If assets' climate risk exposure is sought to be analysed, challenges may be encountered in terms of coverage. Currently, most market participants fail to disclose sustainability data (*TCFD 2021*). In the early stages of market development, reporting entities mainly focus on the corporate sector, the sector most exposed to climate risk, in particular the companies that are most in demand by investors (*EF 2021a*) and that offer a wider range of data. As a result, data from smaller firms is either missing completely from these databases or only approximate values are given for them, and climate risk exposure measures are assigned based on sector or geographical location rather than company-specific data (*Edwards et al. 2021*). The MNB's experience[11] shows that sovereigns are in a similar situation, in that providing structured data has not been a primary goal for reporting entities, as the required methodology differs from that pertaining to the corporate sector. As regards the coverage of the household sector, the issuers of new green mortgage-covered bonds are faced with a challenge because there is no database on historical energy data of homes (*Wass 2021; Nagy et al. 2021*). Another challenge is that the data available at the reporting entity level usually describe the issuer or company, while issue-specific information may be more relevant in certain cases, as assets may be covered and the financed projects may differ.[12] It is not sufficient to examine climate risk exposures in themselves, because it has to be assessed how much a given company, debtor or issuer can withstand a potential climate risk stress (*Lancesseur – Lorans 2021*).

[10] As regards access to market data, the basic level contains the disclosures of issuers and companies, which should be compiled, analysed and assessed. A major portion of such tasks have been 'outsourced' by market participants even on the traditional bond market, for example to various credit rating agencies and reporting entities, which thus facilitate increased market transparency. This market segment can also be traced on the market for green assets. Although consolidation is underway, there are several service providers on the market right now, with a highly heterogeneous product range (*ESMA 2021*; *Bloomberg 2019*; *Environment analyst 2019*) and varying levels of quality. On the one hand, having many market participants is useful because it generates competition and encourages development in the services sector, but on the other hand it does not promote the establishment of uniform procedures, and the homogeneity of data and reports is poor overall.

[11] This finding is based on the experience gained during the preparation of the MNB's climate-related financial disclosure. The MNB used the available central banking examples (e.g. *BoE 2021; BdF 2021;* ECB: *Alogoskoufis et al. 2021b*) and also consulted with individual central banks and reached out to established reporting entities on the market to gather information on reporting, product range, coverage and methodologies.

[12] This may be especially important in the case of green bonds.

3.1.2. Heterogeneity

Heterogeneity is a huge challenge in the implementation of efficient and uniform disclosure practices. Reporting entities disclose their climate risk exposure reports for various reasons and in different forms (*TCFD 2021*). Investor expectations about reports also vary, and the assets are also different. Therefore, all in all the heterogeneity of supply and demand and the expectations by reporting entities and users pose a massive challenge in establishing uniform disclosure practices (*Table 1*), which of course also affects the opportunities of the entities, for example central banks, using these reports directly or indirectly in their own climate risk analysis.

Table 1
Potential reasons for the heterogeneity of climate risk exposure data

Debtor type	Investor type	Asset type
Reporting opportunities and resources vary by debtor Examples: – retail mortgagor* vs. professional corporation – carbon-intensive vs. carbon-neutral industry – regulatory expectations vs. investor expectations	Demand for information may differ by investor Examples: – retail investors vs. banks offering green loans – neutral investors vs. fund buying green bonds – special target function of ethical investors**	Type of financial assets determines reporting Examples: – rating requirement of household mortgages vs. commercial real estate mortgages – rating requirement for standard vs. green bonds vs. bonds tied to a sustainability goal

Note:

**In the case of households, information and attitude are also crucial. For more on this, see: Bethlendi – Póra (2021).*

*** These investors may primarily strive to understand the transition paths presented in TCFD reports as well as the implemented or planned steps to achieve the Paris climate goals. Traditional investors seek to strike a balance between risk and returns, while 'green investors' may also focus on climate VaR calculation, stress testing and the creation of a scoring system.*

Another challenge in connection with heterogeneity is the lack of validation. The principal–agent problem is quite pronounced on the market for green assets. Even in the case of traditional bonds, although rating is performed by an external party, the credit rating agency, that agency is typically financed by the issuer. In the case of green bonds, having an external, independent credit rating agency may not be required, as issuers are responsible for producing their own reports and compiling data (*MNB 2022*). Therefore, even entities in the same sector and financing similar projects may exhibit different effects, and such data cannot be validated.

3.1.3. Limits to the usability of credit ratings

On the traditional securities market, investors can also gain a picture of the risk profile of their portfolio using credit ratings. As part of the rating process, credit rating agencies need to take into account sustainability risks, but only if they exert a meaningful financial impact at the relevant 3–5-year rating horizon. As climate risks have a longer horizon than that[13] traditional credit ratings only have limited applicability from a sustainability perspective, and climate risks have not been incorporated into credit ratings in the form expected by the market.[14]

Utilising the environmental component of the ESG ratings used as a proxy for sustainability data may be misleading in capturing climate risk exposures. Several reporting entities prepare an ESG rating, but (1) there is a weaker correlation between the ratings of the different service providers than in the case of traditional credit ratings, and (2) the weighting of the climate risk aspect used in ESG ratings also varies, so it has limited use in capturing climate risk exposures (*Berg et al. 2019; Dimson et al. 2020*). Unlike on the market for credit rating agencies, there is no uniform European regulation in effect pertaining to ESG rating agencies and their ratings, which is detrimental to comparability and transparency (*ESMA 2021; IOSCO 2021*).

3.2. Methodology

3.2.1. Metrics used and modelling limitations

Besides coverage and data quality, the market also faces challenges in connection with the metrics and methodologies used. One key issue is that certain metrics may not have a straightforward interpretation, and comparability across different issuers (e.g. sovereigns and the corporate sector) is problematic due to divergent methodologies.

- *Appropriateness of time series.* One precondition for climate risk exposure modelling is the availability of data of sufficient quality and quantity. The length of the available time series and the amount of data are limited because only Europe

[13] Carney, M.: *Breaking the tragedy of the horizon – climate change and financial stability*. Speech at Lloyd's of London, London, 29 September 2015. https://www.bis.org/review/r151009a.pdf. Downloaded: 9 February 2022.

[14] As regards climate risk factors, certain credit rating agencies offer climate-adjusted PD and rating besides the traditional ratings (e.g. S&P Climate Credit Analytics, Climate Risk Gauge). There are reporting entities that calculate their own PD effects using models (*Janosik – Verbraken 2021*). Fitch has a service called ESG Relevance Scores, which helps investors determine the relevance and weighting of different ESG factors in credit ratings. According to the analysis of Fitch, environmental effects currently have a low significance in its credit ratings: for example, only 3.1 per cent of the credit rating of non-financial corporations considered this a major factor (*Fitch 2021*).

and the US have major securities holdings,[15] but even this market is dwarfed by traditional markets, and green markets are also relatively young. The liquidity of securities may also pose a challenge (*Fender et al. 2019; Boutabba – Rannou 2022*). Another crucial issue when it comes to modelling is the relevance of historical data in projections.

- *Heterogeneity of metrics.* On the traditional securities market, credit ratings condense information well, and they are comparable in terms of their methodologies and results. Climate risk exposure analysis is less developed than this. There is a market consensus that risks should be analysed by dividing physical and transition risks. However, different reporting entities analyse different drivers of physical risks, translating climate risk exposures into relative riskiness, for example producing a score of 0–100 (*BoE 2021; BdF 2021*), while others use financial indicators, for example the CVaR (*MSCI 2020*) for this purpose. The same applies with regard to transition risks: the energy mix is usually used for sovereigns, while basic carbon-exposure indicators are used for firms (*Faiella et al. 2021; BoE 2020*).

- *Interpreting the metrics.* According to TCFD recommendations,[16] the most widely used metric is weighted average carbon intensity (WACI), which is presented in more detail in the section on methodological questions. However, there are a number of unresolved questions in interpreting the WACI, which is also acknowledged by the TCFD (*TCFD 2017*). First, the metric is difficult to use in itself, since an entity's total CO2 emissions may rise even when the WACI shrinks. In sovereign WACIs, there are no uniform practices for using either nominal or PPP-based GDP, the currencies and exchange rates that are relevant for calculating this metric, and distortions may be caused because typically national economy figures are calculated for sovereigns. In the case of companies, sector definitions and the utilisation of the relevant average WACI values may also be misleading, as companies may vary widely within the same sector, so using company-specific information is difficult to avoid, but there may be significant data constraints in this area.

[15] There is wide variation globally in green bond issues. The first green bond was issued by the European Investment Bank (EIB) in 2007, while the first Western European green mortgage-covered bond was issued in 2015 (*Kidney 2015*). However, the first Hungarian green securities were only issued in 2020, and mortgage-covered bonds have only been issued since 2021. Besides the age and size of the market, its liquidity is also important, and certain targeted initiatives also help boost liquidity (e.g. German and Dutch twin bond issues). Banks are also increasingly seeking to utilise the positive risk opportunities presented by green lending, which is also supported by supervisory authorities through preferential capital requirements (*Billio et al. 2020; MNB 2020; MNB 2021a; MNB 2021b*).

[16] Task Force on Climate-related Financial Disclosures

3.2.2. Definitions and requirements

A central issue related to the green asset market and its continued development is the existence of a uniform, accountable set of definitions and requirements for the different parameters. Reporting is based on defining the parameters along which loans and securities can be deemed green, as well as the uniform procedure for disclosures (*MNB 2022; EF 2021b*).

- *Missing and different definitions.* Besides laying down disclosure requirements, regulators also play an essential role in connection with the definition of securities and loans. Centrally determined requirements can address greenwashing, improve standardisation, comparability and market efficiency, and also provide a solid basis for continued development. Relevant regulatory requirements may include aspects determined at the EU level,[17] but countries and central banks may have their own special requirements as well.[18] Along with the regulatory authority, the central bank asset purchase programmes also determine requirements (*MNB 2021c*). In this respect, regulation follows the development of green securities markets with a lag.[19]

- *Parallel standards.* The market standards determined by the Climate Bonds Initiative (CBI) and the International Capital Market Association (ICMA) (*CBI 2019; CBI 2021; ICMA 2021a*) are the most widely used on the green securities market, and although they are not binding regulations, they can be used as points of reference. In addition to the sustainability definition, another advantage of the standards is that they lay down principles for disclosure. On the green securities market, these standards provide a very similar framework of definitions, but they also entail highly divergent regulations in terms of disclosures and issues, which hampers the development of a uniform procedure on the market. Verifiers assess the frameworks and evaluate their compliance with these standards, but besides controls, issuers also play a vital role in establishing sustainability conditions and ensuring compliance with the requirements. The reports published by the verifiers are heterogeneous in their scope and content,[20] and issuers' green frameworks are

[17] The EU's green taxonomy has been adopted, but the technical details have not been fully developed and implemented (*EU 2020; EU 2021a*), the EU's green bond standard is being prepared (*EU 2021b*), so there is currently no international regulation setting out uniform requirements for the parameters of sustainable financing objectives or sustainable financing transactions.

[18] One might think of different regulations on mortgage-covered bonds. Hungarian regulation (*JHT 1997*) does not treat green and non-green bonds differently, unlike for example the requirements in Luxembourg (*LUX 2018*), which are unique in the EU for now, due to their green focus. The EU's rules on mortgage-covered bonds (*EU 2019*) are consistent with Hungarian regulations, but they do not have a green focus.

[19] There are currently no capital market laws on investor rights related to green bonds, issuer obligations and legal consequences.

[20] For example, in the case of Hungarian green mortgage-covered bonds, all four issues conducted until the end of 2021 occurred with a different rating (OTP: https://www.otpbank.hu/OTP_JZB/file/JZB_Fuggetlen_jelentes_2021.pdf; Unicredit: https://www.unicreditgroup.eu/content/dam/unicreditgroup-eu/documents/en/investors/ESG-investors/Sustainability-Bonds/UniCredit_SPO_18_6_2021.pdf; ÁKK: https://akk.hu/download?path=974f9745-4920-4979-a389-ca51a3a02cec.pdf; Takarék: https://www.takarekjzb.hu/files/22/84149.pdf).

also detailed to varying degrees, and there are no uniform disclosure requirements defined by the standards for impact reports.[21]

- *Green default problem.* There is no central register for the reports,[22] and if issuers deviate from the recommendations, they do not face clearly defined legal consequences. Standards are typically applied on a voluntary basis, which undermines accountability, since there is no formally determined sanction for deviating from the standards ('green default'). This also means that as green frameworks are usually not part of a bond's basic documentation, issuers have significant room for manoeuvre, while investors can only respond to issues by selling the bond, and no other legal options are available to them.[23]

Securities market segments function appropriately if the market ecosystem built around them functions efficiently and well (*mature markets*[24]). This includes the 'voluntary' development of procedures and practices, just like the binding regulatory expectations. Unlike the traditional bond market and mortgage market, the green asset market ecosystem has not yet solidified it is still a work in progress. In this context, the most important parts of the system (investor base, issuers, best practices on the market, regulatory requirements, cleansing of the market and services of data providers) change and develop dynamically. This can also influence climate risk exposure transparency: a more mature and thus more stable market is more likely to develop generally accepted standards that enable environmental sustainability reporting.

[21] For example, ICMA publishes a list of metrics (*ICMA 2021b*), but it is not binding for the issuers, and thus the impact reports published by issuers vary widely: certain issuers provide information at the project or security level, while others do so for the entire portfolio, with differences in format, scope of the reported data, metrics used and reference date (see, for example: *ADB 2021; EIB 2020; KfW 2021*). The MNB's FX reserves have included a dedicated green bond portfolio since 2019 (*MNB 2019*). The MNB first prepared a publication on the climate risks of the portfolio in 2021 (*Elek et al. 2021*); the backbone of that analysis was the compilation and assessment of issuers impact reports. In the course of this work, the MNB consulted with certain issuers and other organisations holding green bond portfolios, and it faced similar challenges in preparing the report as other market participants (*EF 2021b*).

[22] Companies on the market have started compiling impact reports and selling the related service as a product, with varying coverage (e.g. Green Asset Wallet). Currently, investors can typically rely on their own compilations when it comes to impact reports, requiring huge resources (*EF 2021b*).

[23] The EU's green bond standard is expected to be a major step forward in this regard.

[24] The maturity/immaturity of markets and the reliability/absence of data and models also affect prices. Despite the relevance of climate risks, estimates suggest that current asset prices do not incorporate climate risk considerations (*Mastouri et al. 2021*; *Stroebel – Wurgler 2021*).

4. Central bank practices in measuring exposure to climate risks

The following chapter presents the key international recommendations for climate exposure reporting as well as the available practical examples for analysing central bank balance sheets.

Having recognised the challenges posed primarily by the information gaps and the lack of uniform methodology, the G20 Financial Stability Board created the Task Force on Climate-Related Financial Disclosures (TCFD) in 2015 to identify the necessary information that facilitates the assessment of climate-related risks and opportunities. Climate-related reporting requirements used to vary widely (*OECD 2015*), and therefore the establishment of the TCFD and its harmonisation efforts so far are major milestones on the road towards transparent climate-related financial disclosure (*Carney 2020*).

In 2017, the Task Force published its recommendations, which are organised around four thematic areas and can be adopted by wide range of institutions and organisations (*Figure 2*). The four areas (governance, strategy, risk management and metrics and targets) represent the main operational elements of economic entities, thereby enabling the interpretation and implementation of the recommendations. As transparency improves, climate risks can be appropriately incorporated into strategic decision-making processes, facilitating more efficient market prices and the capital flows necessary for a green transition.[25] The present study focuses on metrics and targets.[26]

[25] The TCFD recommends that the disclosure on climate-related risks and opportunities form part of organisations' annual reports (e.g. *DNB 2021*). This is because most financial supervisory authorities and international requirements compel publicly traded companies to publish material information in their annual financial reports.

[26] The financial sector's TCFD reporting practices are summarised by *Carlin – Fischer* (*2020*).

Figure 2
Four main areas of climate-related financial disclosure

Governance
The organisation's governance as pertaining to climate-related risks and opportunities

Strategy
The actual and potential impact of climate-related risks and opportunities on the organisation's business model, strategy and financial planning

Risk management
The processes used by the organisation to identify, assess and manage climate-related risks

Metrics and targets
The metrics and targets used for assessing and managing climate-related risks and opportunities

The publication of reports analysing climate risk exposures has not yet become widespread among central banks.[27] The Bank of England publishes its analysis on climate change in a separate report, while the Dutch central bank incorporates its results into its annual report, providing little detail. One should also mention the French central bank's Responsible Investment Report (*BdF 2021*), which examines sustainability issues on a broad horizon, covering other risks besides climate change. The methodology of the central banks publishing a separate TCFD report, i.e. the Bank of England and the Banque de France is presented below, along with the methodological background of the Magyar Nemzeti Bank's upcoming TCFD report[28] pertaining to the climate risk exposure analysis of financial assets.

[27] Since the establishment of the Network for Greening the Financial System (NGFS) in 2017, an increasing number of central banks and financial supervisory authorities have been actively working to ensure that the objectives in the Paris Climate Agreement are met, that the global financial system can better address climate risks and that capital flows facilitate green and low-carbon investments. The strategic objectives of the NGFS are achieved, for example, by developing and popularising best practices for its members. In the course of this, the NGFS set up working groups in 2021 to assess climate risks and prepare TCFD-compatible reports. The NGFS strives to establish best practices to ensure the better comparability of central bank reports (*NGFS 2021*).

[28] When the present paper was submitted for publication, the MNB's TCFD report was still being prepared. The methodology of the MNB's climate-related financial disclosure was designed taking into account three factors: TCFD recommendations, existing central banking publications, available data.

4.1. Transition risk

Transition risk refers to situations when the value of financial assets changes in relation to the transition to a low-carbon economy. Three indicators measuring the transition risk of (central bank) portfolios are presented below, with a special focus on their relevance for the MNB's climate-related financial disclosure:

- WACI,
- brown share of the portfolios,
- energy mix.

4.1.1. Weighted Average Carbon Intensity

The TCFD recommendations include a WACI indicator used for quantifying indirect greenhouse gas emissions. It was directly developed for analysing corporate portfolios and was adapted for sovereign assets by the MNB, as in the analyses of the British and French central banks. This metric quantifies the average carbon intensity of portfolios, weighted by the share of the assets within the portfolio.

The MNB analysed the climate-related impact on financial portfolios using end-2021 balance sheet data as well as the latest available greenhouse gas (GHG) emission information and the corresponding GDP data, using the 2019 GHG and GDP data for FX reserves and 2020 data for Hungarian assets. For most portfolios, data come from Eurostat databases, with the exception of the FX reserve portfolio, which also has a large exposure to entities outside the European Union.

- The government securities purchase programme and the corporate exposures, such as the Bond Funding for Growth Scheme (BGS), the Funding for Growth Scheme (FGS) and large enterprise loans, were analysed using data from the Eurostat Air Emission Accounts also available in breakdown by sectors (based on NACE Rev. 2 codes).
- The carbon-intensity of FX reserves was calculated using the UNFCCC's National Inventory on GHG emissions and the GDP data from the OECD and World Bank databases.

To take a practical example, the average carbon-intensity of sovereign portfolios measures the GHG emissions necessary for the production of one unit of GDP. In 2021, the average carbon-intensity of the sovereign exposure in FX reserves was 287 tonnes of CO_2e/EUR million in GDP. This means that during the economic activity financed by FX reserve investments, GDP worth EUR 1 million was produced while entailing greenhouse gas emissions of 287 tonnes in CO_2 equivalent.

With respect to the carbon-intensity methodology used for sovereign portfolios, the MNB employed a similar approach as the previously published reports by the BoE and the BdF (*Table 2*). The BoE also used UNFCCC GHG emission data to analyse its portfolio. GDP data were taken from the World Bank database, however, the WACI's denominator used GDP data measured at purchasing power parity rather than nominal GDP. The advantage of the carbon-intensity calculated with nominal GDP is that it ensures greater consistency in the analysis of various asset classes, which is an important principle in the TCFD recommendations. By contrast, PPP GDP is a statistical measure specifically used in international comparisons, adjusting for the distortions caused by different price levels. The issue of the GDP used in the denominator can cause major differences mostly in the case of developing countries, so the MNB's report also describes this methodological aspect in connection with Hungarian government securities purchases. Unlike the MNB and the BoE, the BdF used a third-party analysis firm (Trucost) to prepare its report. The calculation formula of the WACI is the same in the BdF report, but no information was given on the source of data. Nonetheless, third-party analysts also usually base their analytical activities on publicly available databases.

Table 2
Central bank methodologies in measuring the carbon-intensity of sovereign exposures

	Magyar Nemzeti Bank	Bank of England	Banque de France
Formula	$WACI = \sum_i \frac{market\ value\ of\ exposure_i}{market\ value\ of\ the\ portfolio} * \frac{GHG\ emissions\ of\ the\ country_i}{GDP\ of\ the\ country_i}$		
GHG data	UNFCCC National Emissions Inventory	UNFCCC National Emissions Inventory	The BdF did not provide more information on its chosen data sources
GDP data	OECD, World Bank: nominal GDP	World Bank: GDP measured in PPP	

The carbon-intensity methodology of corporate portfolios used by the MNB and the other two Western European central banks differ, related to the data access challenge addressed in the paper (*Table 3*). The overwhelming majority of the corporate exposures of the BoE and the BdF are held against global corporations that publish a detailed report on their revenues and spearhead GHG emissions reporting efforts. Under pressure by various stakeholders (e.g. regulators and consumers), the largest companies in the world have started reporting on their GHG emissions: the corporate carbon-intensity metric recommended by the TCFD (firms' GHG emissions divided by revenues) can be produced easily for portfolios containing such companies. By contrast, in order to calculate the carbon-intensity of portfolios containing investments in small firms, workarounds and approximations are needed, due to the gaps in the corporate GHG emission data and the constrained revenue databases. As the MNB's balance sheet contains a large exposure vis-à-vis the

Hungarian SME sector (FGS programme), the central bank measured the carbon-intensity of the corporate portfolios using the sectoral GHG intensity data based on value added found in the Eurostat database. The carbon-intensity of corporate portfolios is thus the weighted average of the GHG intensity of the different corporate sectors and the sectors' share within the portfolio.

Table 3
Central bank methodologies in measuring the carbon-intensity of corporate exposures

	Magyar Nemzeti Bank	Bank of England	Banque de France
Formula	$WACI = \sum_i \frac{s.\ market\ value_i}{p.\ market\ value} * s.\ \mathrm{GHG}int._i$	$WACI = \sum_i \frac{market\ value\ of\ exposure_i}{p.market\ value} * \frac{corp.GHG\ emissions_i}{corp.income_i}$	
GHG data	Eurostat (Air Emissions Intensities): sectoral GHG intensity relative to value added	Corporate reports	The BdF did not provide more information on its chosen data sources

Note: s.=sector, p.=portfolio, GHGint.= GHG intensity, corp.=corporate.

4.1.2. Brown share

Another metric used for analysing transition risks is the share of the portfolios' carbon-intensive assets (brown share). The TCFD recommends using the Global Industry Classification Standard (GICS) for identifying high carbon-intensity industries. According to the TCFD's assessment, the energy and utilities sectors (except for water utilities and renewable energy firms) are the most carbon-intensive; therefore, the financial exposure to the companies in them should be assessed. Instead of the GICS classification, the MNB used the NACE Rev. 2 sectoral classification, which largely overlaps with the carbon-intensive sectors in the GICS. The examination of such corporate exposures is of special importance for investors, as the transition to a carbon-neutral economic structure will pose the greatest challenge to high carbon-intensity firms, so those are the riskiest in terms of technology and regulation as well. Out of the corporate exposures on the MNB's balance sheet, the shares of the carbon-intensive assets in the FGS and BGS portfolios were calculated.

The advantage of the methodology based on sectoral classification is that the analysis does not require complex data, coverage is appropriately transparent and comprehensive, and it also facilitates comparison across asset classes. On the other hand, the drawback of this classification is that even in the most carbon-intensive sectors, there may be firms that strive to achieve carbon-neutrality with new, innovative technologies, and, conversely, highly carbon-intensive companies may operate in low-carbon sectors. In the future, this could be solved by the widespread measurement and transparent communication of corporate GHG emissions, i.e. individual company-level data. Another distortive effect of the NACE Rev. 2-based

sectoral classification may be that renewable energy firms are not separated from traditional businesses using fossil fuels.

Compared to the MNB's sectoral classification approach, a more focused method was used by the BoE and the BdF. The methodological difference is once again attributable to the different level of detail in reporting and the challenge posed by the availability of data (*Table 4*). The sectoral analysis may provide an appropriate approximation for investors' risk exposure, but a more accurate picture can be gained if company's revenue structure is examined. Companies are not exposed to transition risks because they are classified as belonging to a carbon-intensive sector based, but because a major portion of their revenues come from carbon-intensive activities.[29] Thanks to the corporate reports, the BoE and the BdF looked at the percentage of the revenue of the companies in the portfolio related to carbon-intensive activities (production of fossil fuels and energy generation based on that). Besides the above basic metric, the BoE also estimates the portfolio's risk exposure for a broader group of activities, taking into account the refining and distribution of fossil fuels.

Table 4
Central bank methodologies in measuring the carbon-intensive assets of corporate exposures

	Magyar Nemzeti Bank	Bank of England, Banque de France
Formula	$\frac{market\ value\ of\ carbon\text{-}int.s.}{p.market\ value}$	$\frac{revenues\ of\ carbon\text{-}int.activities}{total\ corporate\ revenues}$
Carbon-intensive activities	Energy and utilities sectors	Fossil fuel production Fossil fuel-based energy production
Sector classification	NACE Rev. 2	N/A

Note: s=sector, p=portfolio, carbon-int.=carbon-intensive.

4.1.3. Energy mix

To meet the objectives of the Paris Agreement, there must be a major shift in the global energy mix away from burning fossil fuels towards using renewables. One way of measuring the risks arising as a result of this transition process could be the analysis of the energy mix of securities issuers. The methodology helps better assess the exposure of the countries in a given portfolio to the risks related to the establishment of a carbon-neutral energy system. Countries where more substantial changes are needed due to the large share of fossil fuels are obviously

[29] The two are basically closely related, and is practice has shown, more and more traditional energy firms venture into the territory of renewables, thereby diversifying their revenue structure and reducing transition risks.

more exposed to transition risks. In its report, the MNB addressed the sovereign exposure of the FX reserves and Hungarian government securities purchases.

The analysis examined the energy mix of the sovereign securities issuers represented in the FX reserves. The energy mix of a sovereign portfolio is the weighted average of the energy mixes of the issuing countries in the portfolio, weighted by their shares in the portfolio. The benchmark used for the analysis was the portfolio represented as IMF COFER,[30] and a forward-looking estimate benchmark was used in the form of the Sustainable Development Scenario (SDS) published by the International Energy Agency (IEA). The SDS is an integrated scenario that determines the path leading to reliable, sustainable and modern energy services, contributing to the mitigation of pollutions and effectively combats climate change (*IEA 2021*).

The MNB's energy mix analysis for sovereign exposures is the same as the one published in the 2020 report of the BoE. In its latest report in 2021, the Bank of England replaced this static analysis based on backward-looking data with a forward-looking method. The new approach looks at the portfolio's so-called warming potential, estimating the heating scenario that is consistent with the future GHG emission path of the sovereigns in the portfolio, and establishing whether or not the portfolio itself meets the 1.5–2°C target of the Paris Climate Accords. The analysis is mostly based on the results of the Climate Action Tracker research project. This independent research project seeks to examine the impact of implemented or planned GHG mitigation measures on the GHG trajectory of the corresponding countries, in order to determine whether the countries can meet international targets. One advantage of the analysis is that it focuses on the future, but it is thus also highly uncertain, as countries have repeatedly backtracked on their commitments and measures in recent decades. The analysis does not cover every country, so it only has limited applicability for diversified portfolios such as the MNB's FX reserves. Similar to the new methodology of the BoE, the BdF uses the warming potential of the portfolios.

4.2. Physical risk

Physical risk means that the change in climatic conditions, such as the rise and variability in average temperatures, or a shift in the amount and distribution of precipitation, including droughts and floods, might affect the value of the financial assets on institutions' balance sheets, in this case the balance sheets of central banks. Assessing physical climate risk exposures involves major technical challenges, requiring detailed geographical data to determine the seriousness of the potential weather events at various locations.

[30] The IMF COFER (Currency Composition of Official Foreign Exchange Reserves) represents the currency composition of the world's FX reserves.

Physical risk results show the relative riskiness of entities within the analysis universe. The scores of the risk categories show a percentile ranking, ranging 0–100, where 0 means the lowest level of risk, while 100 denotes the highest exposure. The result of the methodology points out the riskiest areas and entities, potentially requiring further analysis. In the MNB's first TCFD report, the analysis of physical risks covers a smaller group of financial assets on the MNB's balance sheet, namely sovereign exposures and Hungarian large enterprise bonds and loans.

The methodology of analysing the physical risk of sovereign and corporate entities is the same in the MNB, the BoE and the BdF, due to the same third-party analysis firm. The only difference can be found in the practical analysis of corporate assets, where the service provider, utilising extensive company information databases, performs a more detailed analysis of global corporations than in the case of smaller firms. The central banks use the data and models of Four Twenty Seven (Moody's Analytics) in analysing physical risks, with the results of six risk categories taken into account: floods, heat stress, hurricanes and typhoons, sea level rise, water shortage (water stress) and wildfires (*Table 5*). Within the risk categories, a number of indicators are quantified that capture the change in the exposure of the entity (country or company) to physical risks over the forecast horizon (decade to 2030). The scenario used to predict physical risk is based on the GHG trajectory adopted by the IPCC.

Table 5
Physical risk assessment

	Magyar Nemzeti Bank	Bank of England	Banque de France
External data provider	Four Twenty Seven (Moody's Analytics)		
Physical risk categories under review	Floods Heat stress Hurricanes and typhoons Sea level rise Water shortage (water stress) Wildfires		

5. Conclusion

In market-based economies, transparency is of the essence, because without the transparent operation of individual economic entities, resource allocation cannot be efficient. Until now, the transparency requirement was typically interpreted in the dimension of risk, return and liquidity, but the green transition of the economy means that the transparency and availability of environmental sustainability considerations is becoming more important.

One precondition for the successful green transition of the economy is that financial markets take into account and appropriately assess exposure to climate risks. Investors and markets need to be able to analyse and assess sustainability considerations, and climate risk exposure needs to be included in risk models, return expectations and the pricing of financial products, which can be achieved through transparency.

Transparency rests on data, the evaluation and analysis of which requires an appropriate methodology. There are major challenges in green considerations in terms of the content, homogeneity and comparability of data as well as the methodologies and models used. While the traditional securities market offers decades of data and experience, green markets are only 5–10 years old, and they are also tiny compared to the entire securities market. Regulation should solidify on the market, best practices should emerge in disclosure and models, and data transparency should meet the demands of investors, and this all takes time.

The development of green markets and transparency also requires the appropriate attitude of regulators and central banks. Central banks have already committed themselves to transparency related to climate risk exposures, although for now only a few central banks publish their forward-looking climate risk exposure in line with TCFD recommendations. Independent reports were only prepared, or are being prepared, by the Bank of England, the Banque de France and the Magyar Nemzeti Bank. Besides climate-related financial disclosure, the macroprudential and microprudential measures as well as the monetary policy instruments in certain countries, such as Hungary, and asset purchase programmes also increasingly respond to climate risks (*NB 2021d*), which reflects the onset of a 'green turnaround' in the world of central banking.

This paper described the climate risk exposure analysis of financial assets, including the currently identifiable major challenges as well as the practical solutions of the central banks that have already started reporting. Widespread reporting by economic actors[31] requires that uniform rules, definitions and enforceable requirements related to environmental exposure soon be established.[32] This can be promoted by central banks in line with their statutory mandate, by developing their own transparency and establishing the methodological framework for reporting.

[31] Of course, this will also require a change in accounting practices. For more on this, see: *O'Dwyer – Unerman* (*2020*).
[32] It should be noted here that reporting has already started on a voluntary (market) basis, see: *Eccles – Krzus* (*2018*).

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Answering Causal Questions Using Observational Data – Achievements of the 2021 Nobel Laureates in Economics*

Zoltán Hermann – Hedvig Horváth – Attila Lindner

In the 1980s and 1990s, the field of labour economics was at the forefront of combining economic theory, high-level econometric methods and new data sources. The 2021 Nobel Prize in Economics was awarded to David Card, Joshua Angrist and Guido Imbens, who played key roles in this research, for their "empirical contributions to labour economics" (Card) and "methodological contributions to the analysis of causality relationships" (Angrist and Imbens), according to the citation. These methodological innovations are now applied in all fields of economics and in many other social science disciplines. Credible empirical analysis has transformed economics from a rather theoretical discipline into a discipline dominated by empirical results, where even the most fundamental theories can be rejected on the basis of empirical results. In this paper, we review the main methodological achievements of this period, also known as the credibility revolution, illustrated by some economic applications.

Journal of Economic Literature (JEL) codes: J2, J6, I21, I26, C2, C26

Keywords: natural experiment, minimum wage, returns to education, instrumental variables, difference-in-differences, regression discontinuity design

1. Introduction

Between 1985 and 2001, the editor-in-chief of one of the most prestigious journals in economics, the American Economic Review (AER), was Orley Ashenfelter, a professor at Princeton University, PhD supervisor and frequent co-author of two of the three 2021 Nobel laureates in Economics. At the beginning of his tenure, Prof Ashenfelter was perplexed about why a study published in the New England Journal of Medicine (NEJM) (Hearst et al. 1986), analysing the impact of

* The papers in this issue contain the views of the authors which are not necessarily the same as the official views of the Magyar Nemzeti Bank.

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military service on subsequent mortality, comparing drafted and non-drafted age groups during the Vietnam War, had a greater impact among economists than papers in the AER. Around that time, a PhD student of Prof. Ashenfelter, Joshua Angrist, began looking at the labour market prospects of Vietnam veterans, while a colleague at Princeton University, Alan Krueger, subscribed to the NEJM to explore the reasons for the success of its articles. Working with David Card, Prof Krueger found that all NEJM articles had a clear methodological framework, a so-called 'research design', which renders the analysis transparent and the results credible (*Card 2021*).[1] Inspired by this idea they started to work on applying transparent statistical methods in economic research, in order to have a greater impact on public policy and consequently raise the scientific quality of the discipline. The concept of '*research design*' was thus introduced in economics and thanks to the revolutionary work of the laureates, their intellectual mentors and co-authors, it has become the new standard of professional rigour.

But what does this concept, previously unknown in economics, mean? We demonstrate this below with a selection of examples from the laureates' works, which illustrate both the methodological revolution taking place in the discipline and how this methodological revolution has advanced our knowledge of long-debated economic issues.

2. Answering causal questions using observational data: Natural experiments and research designs

The fundamental aim of most applied research is to explore causal links. In life sciences, the most common method is randomised controlled trials (RCT). For example, when testing new drugs, patients are randomly assigned to a treatment group and a control group, and the effect is measured by comparing the outcomes of the two groups. On average, the various characteristics of the members of the two randomly selected groups are the same on average – therefore, the difference between the two groups after treatment cannot be explained by anything else than the effect of the drug. The opportunity for this type of experiment is very limited in the social sciences. Still, in many cases we can find comparable treatment and control groups, in which – although the individuals observed are not randomly assigned to groups – the resulting situation is similar. During the Vietnam War, conscription was performed by way of draft lotteries: therefore, it was randomly decided who was drafted and who stayed at home. Public policy reforms can also create similar situations. People born in a given month have a different compulsory

[1] Zipperer, B.: *Equitable Growth in Conversation: An interview with David Card and Alan Krueger*. April, 2016. https://davidcard.berkeley.edu/interviews/interview%20with%20Card%20and%20Krueger.pdf. Downloaded: 22 February 2022.

schooling or pension age than those born in the next month. The minimum wage for people living in a particular US municipality is different from that in a similar municipality a few kilometres away, just because it belongs to another state. These situations are called natural experiments or quasi-experiments. If we can identify and leverage them in the analysis, we can convincingly identify causal effects without randomised controlled trials (RCTs). David Card, Joshua Angrist and Guido Imbens were crucial in the development and dissemination of this approach. Their work involves numerous applications, as well as the theoretical development of analytical methods.[2] This meant a radical change of approach from the previous practice in the social sciences, which tried to verify causal effects based on the statistical correlation of two phenomena. In the following, three examples that exploit various quasi-experimental situations and research designs are presented. All three cases led to results with important theoretical implications as well.

2.1. What we have learned about how the labour market works

In the 1980s and 1990s, labour economics was at the forefront of combining economic theory, high-level econometric methods and new data sources.[3] One excellent example is the economic debate on the minimum wage, to which a number of famous economists contributed (e.g. George Stigler and Milton Friedman, who was later awarded the Nobel Prize).

The minimum wage dispute was basically about what constituted the right theory of labour markets. According to the standard theory, the market for low-paid workers is competitive, and therefore wage increases lead to a loss in employment (*Stigler 1946*). In a (perfectly) competitive market, supply and demand are in equilibrium. With the introduction of a minimum wage, this equilibrium breaks down. Higher wages lead to a lower demand for labour, as labour becomes more expensive, and a higher supply of labour, as more people want to work for higher wages. As a result, minimum wages lead to a significant employment loss and unemployment.

In contrast to the standard theory, many have argued that the minimum wage does not lead to significant employment losses. For example, *Richard Lester* (*1947*) argues that the standard theory incorrectly assumes that managers apply the mathematical models of profit-maximising firms. This was backed up by surveys of company managers asking about what determines the number of people they employ. Interestingly, the most important factor for managers was not the cost of labour, but rather demand for their products.

[2] The methods applied are illustrated by examples; therefore, we rely in the following on the articles of Card and Angrist. Imbens was instrumental in developing the methodology, which is not discussed in detail here.
[3] *Interview with David Card*. Federal Reserve Bank of Minneapolis, 1 December 2006 https://www.minneapolisfed.org/article/2006/interview-with-david-card. Downloaded: 22 February 2022.

However, Lester's questionnaire approach was subject to serious criticism. Nobel laureate *Milton Friedman* (*1953*) argued that the laws of competition enforce profit maximisation even if managers do not literally solve mathematical equations. According to the argument, only managers who can figure out how to run a company efficiently and maximise profits will be successful because of competition, even if they cannot express it as clearly as mathematical equations. Milton Friedman used the example of a pool player to illustrate the argument: a good pool player cannot describe exactly where to hit a billiard ball using mathematical equations, yet if we want to understand the path of the billiard ball, we can only do so using mathematical equations. According to the argument, economic models should be tested on the basis of their predictions (e.g. whether the minimum wage reduces employment) and not on the basis of their assumptions (whether firms' demand for labour is determined by profit maximisation).

The debate on the minimum wage has therefore focused on testing the prediction of the standard theory. Early empirical results showed that the minimum wage significantly reduced employment (*Brown et al. 1982*). For this reason, by the 1980s and 1990s, the vast majority of economists believed that the minimum wage was doing more harm than good. A revolutionary study by *David Card and Alan Krueger* (*1994*) broke this consensus.

The early empirical results were mostly based on time-series analysis: the correlation between the minimum wage rate and unemployment or employment over time. The main problem with this approach is that the minimum wage rate is not simply the result of chance, but of a complex political decision, which can depend on many other factors. For example, if the minimum wage is raised more frequently under a left-wing political administration or during recessions, it is possible that the correlation of the minimum wage with employment reflects the impact of other factors, not just that of the minimum wage increase alone.

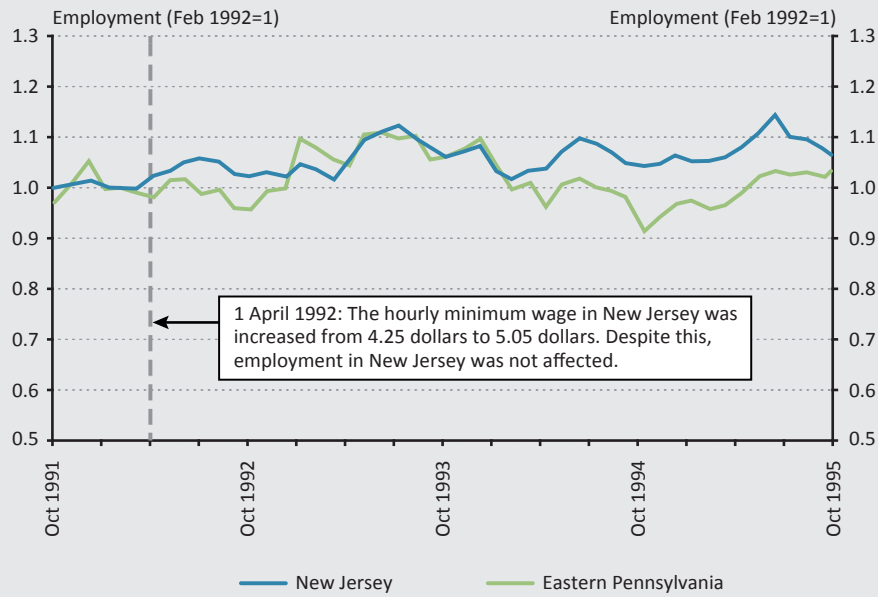
To solve such problems, *Card and Krueger* (*1994*) applied the so-called '*difference-in-differences*' estimation method to empirically analyse the effects of the minimum wage. The authors took advantage of the fact that the minimum wage in the United States is (partly) set at the state level. The state of New Jersey raised the minimum wage in April 1992, while neighbouring Pennsylvania did not. As economic conditions in New Jersey and in the eastern counties of Pennsylvania are very similar, in many respects a quasi-experimental situation arose where the minimum wage is raised in one area (treatment group), while there is no increase in another very similar area (control group).

The difference-in-differences estimation method compares the change in employment of the treatment group (New Jersey) with the change in employment of the control group (Eastern Pennsylvania). Since the economy of Eastern Pennsylvania is very similar, using the control group allows us to eliminate the effects of economic factors that would have occurred in New Jersey without the minimum wage increase, and thus provide a more accurate estimate of the causal effect of the minimum wage.

Card and Krueger collected data on employment in fast food restaurants in New Jersey and Eastern Pennsylvania both before and after the New Jersey minimum wage increase. They showed that employment in the treatment group increased relative to the control group, i.e. the minimum wage actually increased employment rather than decreased it. The new analysis, based on a more credible research design, contradicted the previous estimates in the literature that was largely based on time-series analyses. Furthermore, the finding of higher employment was hard to reconcile with the prevailing economic theory.

The difference-in-differences method has become one of the most widely used research designs in applied economics. The advantage of the method is that treatment and control group situations often arise because public policies do not affect everyone to the same extent. The empirical method is based on the assumption that the change in the control and treatment groups would be the same if the treatment group had not received the treatment. This is the so-called '*parallel trends*' assumption, which is often tested by comparing trends before the reform was introduced. *Card and Krueger* (*2000*) is a good example of this. The study uses administrative data to analyse employment trends in New Jersey and Eastern Pennsylvania between October 1991 (6 months before the minimum wage increase) and October 1995 (42 months after the minimum wage increase). The results are illustrated in *Figure 1*.

Figure 1
Impact of the New Jersey minimum wage increase



Source: Royal Swedish Academy of Sciences (2021)

It is clear that employment trends in New Jersey and Eastern Pennsylvania were very similar in the six months prior to the minimum wage increase, while employment in New Jersey increased slightly compared to Eastern Pennsylvania after 1 April 1992. The graph also illustrates that the initial positive effects do not turn negative in the long run: Employment in New Jersey was still higher than in Eastern Pennsylvania three years after the minimum wage increase.

The difference-in-differences method is now often applied in a more developed form, where there is no single control group that resembled the treatment group before the reform, but there are several control observations (country, member state, company, school, etc.), whose appropriately weighted combination fits well ('in parallel') with the pre-reform trend of the treatment group. Guido Imbens played a pioneering role in the development and statistical fine-tuning of this '*synthetic control difference in differences*' method (*Arkhangelsky et al. 2021; Athey – Imbens 2006, 2022*).

Although *Card and Krueger's 1994* analysis has been strongly criticised, subsequent research has supported the main findings of the original study.[4] Examining the effects of 138 large minimum wage increases, *Cengiz et al* (*2019*) found that minimum wage increases have no negative impact on the employment of low earners. After summarising the results of 37 studies on the minimum wage, *Wolfson and Belman* (*2019*) concluded that the impact of the minimum wage on employment is very small and statistically indistinguishable from zero. Nevertheless, it is worth highlighting that these results should always be interpreted in the given context, with the given minimum wage level in mind. Neither *Card and Krueger* (*1994*) nor subsequent studies claim that the minimum wage can be raised beyond all limits without any employment losses.

It is important to note that, with its new, credible methodology, empirical analysis was able to reject previously highly consensual economic theories. The result itself launched an important new direction in research, leading to a more realistic description of the labour market. These new models take into account that most companies not only passively accept market wages, but have some wage-setting power. As a consequence, a certain level of minimum wage can increase employment (*Burdett – Mortensen 1998*; *Manning 2003*). Moreover, Card and Krueger's research on the minimum wage paved the way for the so-called '*credibility revolution*', where fundamental economic and social policy issues should be decided through 'credible' empirical analyses, rather than theoretical debates. As a consequence, the discipline of economics has increasingly shifted in an empirical direction, increasing its scientific validity and impact on public policy.

2.2. Credibility revolution in education research

In educational research, the methodological shift in economics linked to the names of the Nobel laureates and their fellow authors was particularly revolutionary. Prior to the 1980s, mostly sociologists, psychologists and researchers from other social science disciplines were doing research on education policy issues. However, the rigorous but transparent design-based statistical methods rooted in quasi-experimental situations have since attracted many economists to this topic to answer important, policy-relevant questions on individual labour markets. This methodological renewal, the *'credibility revolution'* (*Angrist – Pischke 2010*), has brought education economics to a point of inflection regarding both the number of people working in the field and their research methodology. In this subsection, we review the pioneering work of the Nobel laureates in this field, focusing on

[4] Many respected economists were outraged by *Card and Krueger's* (*1994*) analysis, as they saw it contradicting fundamental economic theories. For example, James Buchanan, who was awarded the Nobel Prize in Economics in 1986, argued that the analysis of David Card and Alan Krueger was unscientific and that such an article had no place in leading economics journals such as the American Economic Review.

two main issues: the returns to education in the labour market and the impact of schools/elite schools on student achievement.

2.2.1. The returns to education[5]

In economic models, wages are usually closely related to workers' productivity. In addition to traditional economic topics, economists turned their attention to education when they recognized that education could play a crucial role in determining workers' productivity. Education is defined as an *investment* in human capital that has a *return*. A fundamental and much debated question in economics is how large this return is and how to measure it. Since the work of *Jacob Mincer* (*1958, 1974*), estimation of the human capital earnings function from observational data, also known as the Mincer function after the pioneering labour economist, has become a standard in this field. The typical form of the equation is:

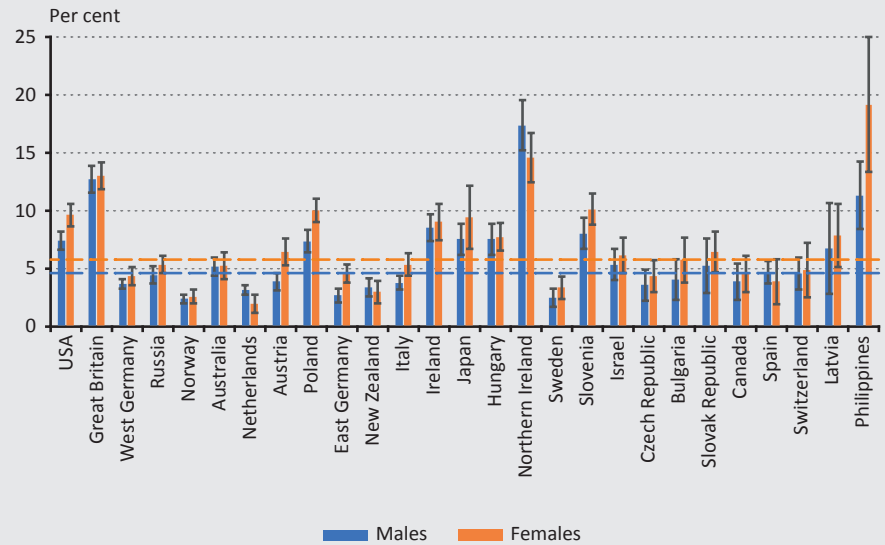
$$log\ y = a + bS + cX + dX^2 + e,$$

where *log y* is the logarithm of earnings, *S* is education (measured in terms of educational attainment or years of schooling), *X* is labour market experience, i.e. the number of years worked,[6] *e* is the residual, which, in the statistically estimated form of the equation, includes the additional control variables (e.g. gender, marital status, union membership, etc.). Mincer derived this equation from an individual educational choice model and it is usually estimated by applying the ordinary least squares (OLS) method. The magnitude of the empirical relationship (*b*) has been measured in numerous contexts, and even though various forms of it have been fitted to the data – for example, the set of control variables or the functional form of schooling or potential labour market experience, the results are very robust: one additional year of education implies approx. 4–10 per cent higher subsequent earnings (*Figure 2*).

[5] This subsection draws heavily on *Card* (*1999*).

[6] The labour market experience is actually difficult to observe, so it is usually approximated by *potential* labour market experience: $A - c - S$, where A is the age of the individual and c is age at the start of compulsory schooling.

Figure 2
Returns to education in different countries, by gender, estimated from the Mincer equation



Note: The grey capped spikes represent the 95% confidence intervals generated by robust standard errors. The horizontal dashed lines indicate the estimated return for all countries pooled. In addition to education, the estimated equation also includes the following variables as controls: year dummies, union membership, marital status, age, age squared, and country dummies in the regression for all countries pooled.

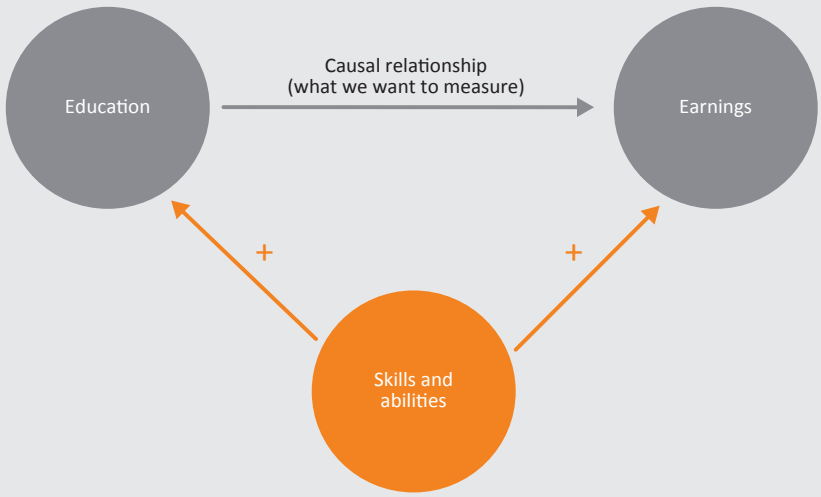
Source: Trostel et al. (2002): Table 2

This finding is often interpreted – misleadingly – as 'an extra year of education *increases* later earnings by about 4–10 per cent'. The word 'increases' may give us the impression that higher education causes higher earnings. Partly, perhaps, because there is a good chance that this causal relationship is what we are interested in. For example, we want to know whether our child should go to university. Or, as public policy advisors, we need to answer the question of whether it is worthwhile to support the expansion of secondary/higher education. However, the results of Mincer type regressions estimated by OLS are not suitable for drawing such conclusions on causation, for several reasons.

First, because the skills and abilities of individuals are difficult to observe: consequently, we usually don't have data on this. However, children with higher abilities are more likely to have better academic outcomes, and thus are more likely to study longer (e.g. go to university). Better skills/abilities, on the other

hand, have a direct impact on earnings, even without higher education.[7] Therefore, when we find a positive relationship between education and earnings without observing skills/abilities, we cannot be sure whether we are really seeing an effect of education, or rather of better skills. This is illustrated in *Figure 3*.

Figure 3
Omitted variables (abilities)



The coefficient estimated from the Mincer equation, $\hat{b}$, combines the direct causal effect of education and the indirect effect of better ability (*ability bias*). Since we expect both to be positive, we say $\hat{b}$ is likely to overestimate the pure causal effect of education, which we are investigating.

The second problem with the causal interpretation of the Mincerian education coefficient is that if there are large differences between individuals in terms of their return to an extra year of education. It is possible that individuals for whom this return is particularly high may choose ('self-select') to complete a higher level of education. In other words, reverse causality is conceivable, which would also strengthen the positive correlation between education and earnings. This again suggests that $\hat{b}$ estimated by OLS might be biased upwards.

[7] Such variables, for which we either have no data or 'forgot' to include them in our regression model, but which are related to both our main independent variable (education) and our outcome variable (earnings), are called *omitted variables*.

Some of the main contributions of the 2021 Nobel laureates in economics were to highlight that correlation does not necessarily imply causation and to develop methods to establish causal relationships using observational data. To do this, they exploited – using the phrase coined by the laureates and their co-authors – 'quasi experimental' situations similar to random experiments, but occurring naturally in real life. In addition to the 'difference-in-differences' method described above, the other and perhaps best-known of these quasi-experimental research designs is the so-called *instrumental variables (IV)* method, which has been frequently used since the 1990s to measure the returns to education.

The essence of the IV framework is illustrated by the blue shapes in *Figure 4*, using the example of *Angrist and Krueger* (*1992*). The research design of the study exploits that during the Vietnam War, those who enrolled in college in the United States could avoid being drafted. However, conscription was performed by assigning a *random draft lottery* number to each military-age man based on their date of birth, who then were drafted in ascending order of their lottery numbers according to the military's personnel requirements.[8] In this particular regulatory environment, the lottery number used for conscription can be considered as an instrumental variable which

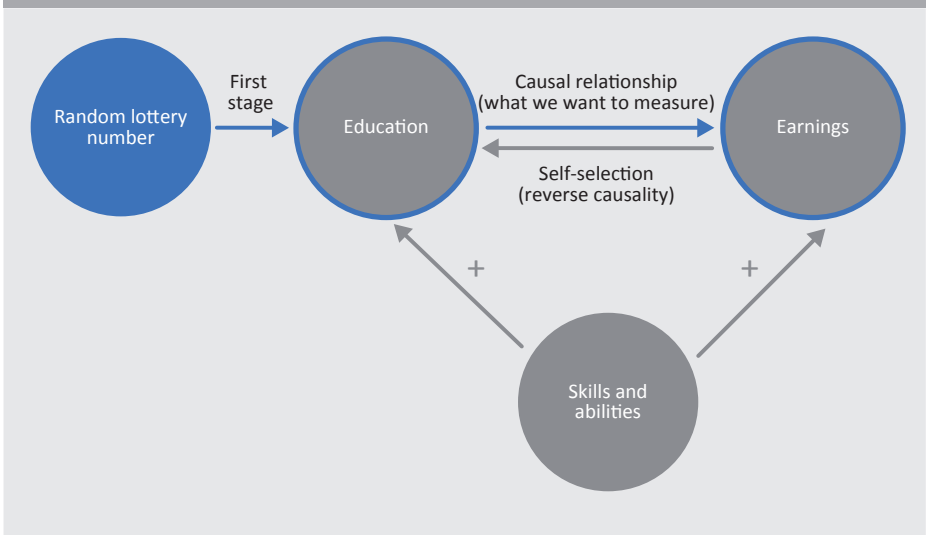
1. may determine educational attainment – as university enrolment was a way of avoiding conscription, those with a lower lottery number (due to being drafted earlier) were more likely to go to university by pure chance,

2. does not affect earnings through any channel other than education, e.g. ability – again, because the draft lottery number is randomly assigned (based on date of birth, regardless of abilities).

In other words, a change in the instrument (a lower lottery number) increases education without changing abilities. As a result, the potential differences in earnings between individuals can only be attributed to differences in the lottery number and hence in education, and not to differences in abilities. In this case, we can be certain that the difference in earnings is *caused* by differences in education, since abilities do not differ as a result of the lottery number.

[8] The same conscription scheme was used by *Hearst et al.* (*1986*), mentioned at the beginning of this paper, and by *Angrist* (*1990*), inspired by them.

Figure 4
Instrumental variables (draft lottery number) mechanism



In general, one major advantage of the IV method is that a 'good' instrument can purge the OLS estimate from both omitted variable bias (stemming from skills in the case of the returns to education) and bias from reverse causality (self-selection).[9] The drawback of the method, however, is that it is very difficult to find a 'good' instrument, because it would have to meet the following two conditions, to put it a bit more rigorously:

1. *Relevance*: the instrument should strongly correlate with the endogenous variable (in our case, education) whose causal effect we are interested in but applying OLS estimation would give a biased estimate due to the omitted variable/reversed causality problems described above.

2. *Exclusion restriction*: the instrument should not be related through any other channel to the outcome variable (in our example, earnings).

To ensure relevance, we use the so-called *first stage* regression, which regresses the endogenous variable (education) on the instrument(s) and other control variables (e.g. potential labour market experience). In this regression, we can determine the relevance of the instrument(s), i.e. whether the instrument is *strong,* in light of the *F*-statistic testing for the joint significance of the coefficients on the instrument(s).[10]

[9] Moreover, it may also address a third problem: the bias arising from the measurement error in schooling/education. See *Card* (*1999*) for more details.
[10] In the article by *Angrist and Krueger* (*1992*) mentioned earlier, it turned out that the draft lottery number as an instrument for education was weak – a low number was not strongly related to whether or not one went to university (*Card 1999*).

Although there are rules of thumb about the *F*-value above which the instrument is deemed sufficiently strong/relevant (*Staiger – Stock 1997; Stock – Yogo 2005*), it is in fact not possible to establish this without any doubt if someone is not fully convinced of the exclusion restriction (validity) of the instrument. A weak instrument that violates the exclusion restriction even if only a tiny bit (affecting earnings also through other channels, not just education) may even increase the bias of the OLS estimate (see details below). The exclusion restriction, however, is particularly difficult to verify, as there is no formal statistical test for it. Thus, the only option for researchers is to argue for it in a detailed and rigorous way, transparently laying out the supposed mechanism of the instrument, i.e. 'where the identification comes from.'

Card's (*1995*) perhaps autobiographically inspired article[11] uses the proximity of one's birthplace to the nearest university as an instrument for education (university degree). This can be regarded as a natural experiment, since the place of birth of an individual can be considered random, but it influences university attendance: it costs less for the individual to go to university if they were born close to one, than if they were born far away. For this reason, those born nearby are more likely to enrol and graduate from university than those born further away, as the argument for the relevance of the instrument goes. At the same time, it is not related to one's earnings whether the individual was born near a university through anything else than the person's degree, says the argument for the exclusion restriction. However, as it turns out, neither of the conditions fully hold: the instrument is only strong among those with lower-educated parents, and places close to universities tend to offer better job opportunities, meaning that proximity to university also affects earnings in other ways, through better local labour market conditions. As in many other IV studies measuring the returns to education, the numerical results in this paper show that the IV estimate far exceeds the OLS estimate. This remains somewhat of an unsolved puzzle, since both the presence of omitted variables (e.g. abilities) and the reverse causality (due to self-selection) would imply that the OLS is biased upwards, so an unbiased IV estimate should imply a lower return. What are the possible explanations for this apparent contradiction?

On the one hand, it is possible that the instrument is both invalid (i.e. does not meet the exclusion restriction) and weak, a combination that can inflate the bias of the OLS estimate. Whether this entirely explains the observation that the IV exceeds the OLS is not considered likely/convincing by the researchers (*Card 1999*). In the case of *Card* (1995), for example, the IV is still about 30 per cent higher than the

[11] David Card grew up on a farm in Canada, but there was a university nearby. He partly attributes his educational attainment to this (*Interview with David Card*. Federal Reserve Bank of Minneapolis, 1 December https://www.minneapolisfed.org/article/2006/interview-with-david-card).

OLS when controlling for an individual's family background, when the exclusion restriction and relevance of the IV are far more convincing.

On the other hand, it is possible that the IV is larger because the instrument also removes the downward bias in the OLS due to measurement error (see *Footnote* 9).

Moreover, many, including *Card* (*1999*), believe that IV studies are most likely to estimate the treatment effect (in our example, the returns to education) for specific groups for whom the return is larger than the population average. To shed more light on this, consider *Angrist and Krueger's* (*1991*) estimate of the returns to education. In this paper, the authors exploit the feature of the US public education system that in most states, primary school starts on 1 September of a given year for those who turned 6 years old before 1 January of that school year, while those who turn 6 on or after 1 January, only start school in the following September. Because of this, a person born on 1 January (in the first quarter of the year) typically starts school at the age of 6 and ¾, while someone born on 31 December (the fourth quarter) starts a year younger at 5 and ¾. Therefore, by their 16th birthday, when they reach the upper compulsory schooling age, those born in the first quarter of the year have been in school for one year less (for just over 10 years) than those born in the fourth quarter. If the quarter of birth is independent of other factors that determine earnings, we can use it as an instrument for education, and the difference in earnings between those born in the first and fourth quarters identifies the return to the difference in their education. However, as Angrist and Krueger point out, we only see education differences between the two groups (those born in the first vs. fourth quarter) among early school leavers, but not among those who go to university or post-graduate education. The differences in earnings are also concentrated in this group. However, this is a special group: they are the ones who are kept in school for a longer period of time exclusively due to the compulsory schooling laws. It is for this specific group that this study measures the returns to education, not for the general population. Yet the returns to education in this group can be very different from those of the general population.

This idea is formalised by *Imbens and Angrist* (*1994*) and *Angrist et al.* (*1996*) in the concept of the *local average treatment effects*. Still using the example of *Angrist and Krueger* (*1991*), the population can be divided into 4 segments according to how much they attend/would attend school if born in the first and fourth quarters:[12]

[12] Note that it is not obvious from the data to which group an individual belongs, since the allocation is based not only on the schooling chosen for the actual date of birth, but also on the so-called counterfactual choice, i.e. what the individual would have chosen if he or she had been born at a different date. The latter cannot be observed. Yet, using the method developed by Imbens and Angrist, we can describe these groups with the characteristics observed in the data.

1. The *always takers*: whether born in the first or fourth quarter, they go to school for 'longer';

2. the *never takers*: whether born in the first or fourth quarter, they go to school for 'shorter';

3. compliers: they attend school longer if they were born in the fourth quarter, than they do if they were born in the first quarter;

4. defiers: they attend school longer if they were born in the first quarter than they do if they were born in the fourth quarter.

Imbens, Angrist *et al.* show that under certain conditions, for example when there are no defiers, the IV estimate estimates the effect of treatment (in our example, education) on the group of compliers.[13] However, the group of compliers may be different for different instruments, for whom the returns to education may also be different. *Angrist and Krueger* (*1991*), for example, find that in the group held in high school by the compulsory schooling laws the return to one extra year of schooling is about 7.5 per cent, which is barely different from the OLS estimate. By contrast, for the group of compliers (those who only go to university if there is one nearby), *Card* (*1995*) finds the return to education – in their case university – to be well above those estimated by OLS.

The analysis by *Angrist and Krueger* (*1991*) has been widely replicated. *Bound et al.* (*1995*) showed that the quarter of birth as an instrument for education is weak, and therefore the IV estimates, even in a large sample, may be inconsistent. This article triggered a whole wave of methodological research, developing practical advice for cases where researchers have many weak *instruments* at their disposal (e.g. *Staiger – Stock 1997*). New solutions to this problem are also emerging today, with machine learning algorithms becoming more widespread.[14]

2.2.2. The effect of elite schools

For education researchers, education policymakers and parents alike, the question of which schools are good and what makes them work better than others is a fundamental one. At first glance, this seems like a trivial question: just look at which schools are at the top of the school rankings available everywhere. These rankings are based on data that show very clearly the achievement of students attending these schools: graduation rates, post-secondary attainment rates, standardised test scores. In most countries there are significant differences between

[13] In addition, the authors have also worked out the details of how to characterise the group of compliers using their characteristics observed in the data.
[14] See, for instance, the application of *Belloni et al.* (*2011*) in *Derenoncourt*'s (*2022*) paper.

schools with regard to these indicators, and usually a few elite schools stand out from the rest.

However, it is also clear that the composition of students in these schools is also very different. As they are very popular, they select the students who can perform the best from a large number of applicants, who then go on to perform really well. But what is the role of selection on the one hand and the school and the higher standards of education on the other? This question is particularly important if the government wants to encourage schools to improve the quality of education, as it requires measuring quality. In the US, several states and metropolitan school districts introduced this type of accountability reforms in the 1990s, and in the early 2000s it was introduced as a federal programme (No Child Left Behind programme).

Researchers have long tried to separate the effects of student characteristics and school quality using various statistical methods. On the one hand, we can try to directly identify the impact of student characteristics by including them as control variables in the analysis. On the other hand, we can look at the change in achievement (the '*value added*') of individual students over time. This approach is based on the assumption that the effect of students' individual characteristics is summed up in their previous test scores, and thus the change in their test scores is more or less attributable to the school. These two approaches, and various combinations of them, are very often used to measure the performance of individual schools or teachers. While everyone agrees that these estimates are generally much closer to the actual quality of schools compared to simple averages of outcome indicators, it is an open question how accurate they are. There is good reason to believe that in some cases, such as in prominent, elite schools, the role of unobserved student characteristics, which the traditional approach above cannot take into account, can be very important. Students who apply to these schools are likely to be more motivated and more diligent, and their academic performance is also a priority for their parents, who invest more in their development in a broader sense. These students presumably progress faster, so that the increase in achievement compared to their previous results is greater, and the value added calculation does not fully eliminate the effect of such selection.

How can we measure the quality of schools more accurately? If we consider school quality as the impact of schools on students' knowledge and skills, we can apply the methods of causal analysis, the logic of natural experiments. Angrist's research has been seminal in this area.

As he pointed out even in his Nobel Prize lecture, one of the issues that has long been a concern of his, and that he and his co-authors explored in several studies, is the effectiveness of so-called charter schools. These are non-public schools that receive public funding under a contract (a '*charter*') with the government (in the

US, unlike in Hungary, this is not usually the case for private and parochial schools), but may follow a curriculum and pedagogical practices different from those in traditional public schools. They often operate in segregated metropolitan areas and are successful in educating poor students who live there. Many see these schools as an opportunity to reform the US education system and expect them to reduce the huge achievement gap between minority and white students. While others believe that selection is behind the success of charter schools, where students and parents are more motivated and engaged than the average student with similar socio-economic backgrounds.

Angrist and his co-authors studied charter schools in Massachusetts, where in the case of over-subscription, lotteries are used to decide who gets into the school (*Angrist et al. 2010*; *Angrist et al. 2012*). Using lottery draw as a natural experiment, the subsequent results of the lucky ones admitted and those who rejected were compared. The IV method was applied, using the result of the random lottery numbers as an instrument for admission. In the case of the schools studied, a significant positive effect was found: the test score gains of admitted students at one school (Lynn), for example, were more than a third of a standard deviation higher in maths and a tenth of a standard deviation higher in reading and writing after one year than their peers' who were not admitted as a result of the random lottery (*Angrist et al. 2012*).[15]

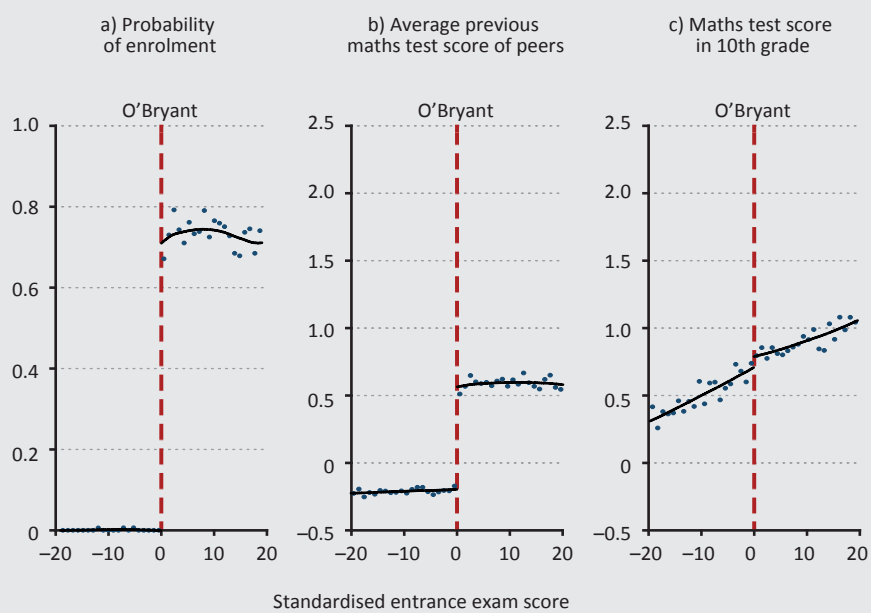
Another issue where Angrist and his fellow researchers have made significant progress is the impact of elite schools (*Abdulkadiroğlu et al. 2014*). In their ground-breaking study, they examined the impact of the three most prestigious elite high schools in both Boston and New York. Students are admitted to these schools solely on the basis of an admission test. A direct comparison of admitted and rejected applicants does not show the effect of schools, as the two groups are very different: admitted students are not randomly selected: they have achieved much better academic results in the past. However, students on either side of the admission threshold, who have just got in and those who have just missed the cut-off, are very similar; we can assume that they do not differ in any of their unobserved characteristics. Of course, the past achievement of students below the threshold is somewhat poorer, and this should be taken into account in the analysis. In such situations, when the probability of being treated suddenly and significantly jumps when a given variable passes some threshold, we can use the *regression discontinuity design*, as Angrist and colleagues did in their analysis of elite schools. Their study has not only contributed to the analysis of the impact of schools, but has also become an exemplary application of the regression discontinuity design.

[15] By comparison, these are large effects; the raw test score difference between black and white students in third grade is almost 1 standard deviation (*Fryer – Levitt 2006*).

The starting point of the method is that receiving the treatment depends on the value of a certain variable (*running* or *forcing variable*). For example, students can be admitted to an elite school if their admission test score is above a certain threshold. Admission test performance also correlates with the subsequent results, which is demonstrated by the regression curve fitted (by some parametric or non-parametric method) to the two variables. The effect of being in the treatment group is shown by the magnitude of the 'jump' observed in the outcome variable at the threshold.

Figure 5 illustrates the results for an elite school in Boston. It is clearly visible that, at the admission threshold, the probability of enrolling in the school increases sharply (panel a), and the composition of peers also changes significantly (panel b). However, contrary to what might be expected, there is no sharp increase in students' subsequent maths test scores (panel c): there is no difference in the subsequent academic achievement of students who were admitted to an elite school and those who were just rejected. This surprising result is expressed also in the title of the study: The Elite Illusion.

Figure 5
Elite illusion



Source: Abdulkadiroğlu et al. (2014): Figures 1, 2 and 4

The zero impact of elite schools on test scores is interesting for several reasons. First, it contributes to the literature on peer effects in education. How does the composition of the class, e.g. whether the classmates are high achievers or disruptive, affect the student? The literature on the issue provides a number of sharply different results, but this effect is very difficult to identify empirically (*Angrist 2014*). The study by Angrist et al. answers this question indirectly. It shows that the average previous test scores of the classmates of students who are enrolled in elite schools are much higher than those who failed to enrol, but this has no effect on the subsequent performance of the student, i.e. in this case the achievement of classmates does not matter (*Abdulkadiroğlu et al. 2014*).[16]

However, the question remains: if they have no real effect, why are these schools so popular amongst parents and students? Would applicants be wrong to chase the illusion of elite education? Or does student achievement as measured by test scores not capture what students gain by studying in these schools? For the moment, these remain open questions, but how strong these preferences are is shown by a recent study analysing elite schools in Chicago (*Angrist et al. 2019*). Here, the authors found that enrolment in elite schools has a negative effect on student achievement, because many of the students not admitted are enrolled in charter schools that do improve their performance. Nevertheless, applicants prefer elite schools to charter schools.

Causal estimation of school effects is only possible in exceptional cases, and the results refer to a specific, often unique group of students and schools. What can we learn from this type of analyses in general? In another recent study, Angrist and co-authors (*Angrist et al. 2017*) used data from the centralised admission system in Boston public schools. When assigning sixth-grade students to high schools, a random lottery plays a significant role in the matching algorithm.[17] Thus, for a very large number of schools, they were able to estimate the causal effect of the school and compare this with traditional value-added-type indicators of school achievement.[18] They found that the school quality estimated by the value-added method does give a biased estimate, but that the bias is not too large and so such data should not be ignored in education policy decisions.

[16] A similar result was obtained by *Angrist and Lang* (*2004*) in a previous study: the achievement of middle-class students in suburban schools in a Boston integration programme was not affected by the appearance of a few poor, black students from the inner city in the classroom. *Angrist* (*2014*) argues that many analyses overestimate the effect of peers, and that it is in fact much weaker than we think.

[17] In Hungary, a similar centralised admissions algorithm matches applicants with schools at both secondary and tertiary level, but there, random elements play a negligible role.

[18] *LaLonde's* (*1986*) study pioneered this strategy in the context of job training programmes.

3. Closing remarks

The emergence of a new approach based on natural experiments has fundamentally transformed the way economics research is conducted, and *Angrist and Pischke* (*2010*) rightly referred to this transformation as the '*credibility revolution*. This required the development of new analytical methods, in which David Card, Joshua Angrist and Guido Imbens played a key role. This brought economics closer to the natural-scientific ideal of understanding and empirically verifying causality. But perhaps more importantly, this new toolkit can help us better understand the economy and society.

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The Role of Data Assets in the Financial Sector*

Gábor Izsák – Alexandr Palicz – Katinka Szász – Balázs Varga

The article presents the anticipated effects of data in the 21st century in the economy, with a special focus on the financial sector. Using successful international examples, it highlights the fact that the transition to a data economy is not merely a measure of efficiency of economic actors but also their key to survival; to ensure this, it is essential that the state assumes a role in making data available, developing competitive digital competences and deepening customer trust.

1. Introduction

As a consequence of the IT revolution in recent years, in addition to traditional production factors, data and the information that can be extracted from data assets have become a major factor in value creation. Unlike capital and workforce, the amount of information is not finite; it is available in continuously increasing volumes, and when used, it is not lost but even promotes the generation of further information. Data can be easily copied and transported, but cannot be easily reproduced once corrupted or destroyed. Since data are not consumed with use, they can be stolen without being lost (*Redman 2011; DAMA 2017*). Compared to already existing production factors, the application of data requires a novel approach and new methods. From a macroeconomic perspective, the economic and social advantages gained from the use of data can be maximised by developing regulated access for third parties, and not by obtaining, possessing and locking data from competitors.

In the age of rapidly increasing volumes of data (big data), developing infrastructure networks (5G) and the Internet of Things (IoT), significantly more data are available in more and more spheres of life; however, human processes are being eliminated in an increasing number of areas by accelerating information processing, through the application of automated decision-making systems. By the end of 2020, global data assets had exceeded 60 zettabytes, and some five billion users and 50 billion devices had been connected to the internet (*Table 1*). With data having the appropriate content and format, automated systems – unlike human resources – are

* The papers in this issue contain the views of the authors which are not necessarily the same as the official views of the Magyar Nemzeti Bank.

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able to generate uninterrupted, error-free responses almost simultaneously with processing. The use of data and the rise of instant decision-making are reflected in several traditional and newly emerged industries, from intelligent self-driving cars and remote health interventions to instant credit decisions and lending by financial service providers.

Table 1
Global data assets and factors promoting their exploitation

	2010	2020	Change
Global data assets (zettabyte)	2	64	3,200%
Data storage costs (USD/gigabyte)	0.1	0.014	–86%
Global internet users (billion)	2	5	250%
Number of devices connected to the internet globally (billion)	5	50	1,000%
Average global internet speed (Mbps)	1.7	25	1,471%

Source: Ali et al. (2015), Statista, Forbes, BBC, Internetworldstats.com

The Covid-19 pandemic has acted as a catalyst for digital transformation, as governments and companies had to immediately find effective responses to massive needs for communication and digitalisation lacking personal contact. In lieu of surveys, questionnaires and theoretical debates, certain data owners have already started to successfully apply forward-looking, innovative solutions to exploit their data assets in a crisis or to promote the recovery from it. The increasing number and speed of online transactions, the appearance of central bank digital currencies make the ubiquity of technology in all branches of the economy more and more obvious.

In the 21st century, due to the emergence of new opportunities and industries built on the exploitation of data assets, data processing and the use of data in economic policy decisions, digital transformation and the promotion of the related economic restructuring are not only an efficiency issue but have become a basic requirement of survival. Ensuring wide access to data improves the efficiency of market and state operations in multiple ways (*European Data Portal 2020*). In particular, this applies to industries such as the financial sector, where operation is based on the availability of the most accurate customer data accessible and their use as effectively as possible. According to international literature, a boost of up to 1.5 per cent to annual GDP may be achieved by creating wider access to available financial data and with stronger use of data in business decision-making (*White et al. 2021*).

In addition to business opportunities, the strategy for using national data assets has gained prominence in most countries from the perspective of the operation of the state as well. Data-driven public administration promotes more targeted state interventions (e.g. epidemic management, benefits) and facilitates more efficient decision-making (transport policy, law enforcement), but even the fiscal space may

expand through effective audits and reduction of the shadow economy (*Van Ooijen et al. 2019*).

2. The role of data assets in the financial sector

One of the cornerstones of the data processing efficiency of competing data-intensive industry actors is what information is available to them and how quickly they are able to use it to generate value-creating results (*OECD 2020*). This in particular applies to the financial and banking sectors, where the analysis of data, the quickest possible extraction of the inherent information and its effective and accurate use have become the most important component of competitive advantage. In the banking sector, increased data processing and use have boosted efficiency in almost all business, competence and back-office areas (*Figure 1*).

- *Client acquisition:* Knowing the demographic characteristics, geographical location, search history and payment history of customers, increased data analytics may result in more efficient customer segmentation, and more targeted marketing offers and cross-sell opportunities may be provided. Advanced identification systems and algorithms allow for online customer identification, providing opportunities for opening accounts online in real-time and expanding the customer base simultaneously, as well as instant selling various banking services (*Chung et al. 2020*).

- *Lending:* Making internal or external banking data as well as state-owned databases accessible allows for comprehensive, automated, online lending. Following the online identification of customers, banks need to obtain information on customers' creditworthiness from several different sources. This information may traditionally include the customers' income situation, wealth or credit history. But creditworthiness can also be predicted by behavioural data such as web search history, shopping habits, geographical location, the type of their device connected to the internet, etc. Through the automated accessibility and analysis of a wide range of data, a wider range of customers become creditworthy, and it also provides the opportunity for real-time credit scoring and loan disbursement. As the time to approval is shortened and access to data is automated, unit costs per customer may be reduced, which may contribute to a reduction in interest rates or to the financing of further developments (*Peterson 2018*).

- *Risk management:* Significant credit losses may be prevented by more advanced risk management systems using a wide range of open data. Most of the data used by advanced risk management systems extend beyond conventional sources as well as traditional, structured ones. Thus, among other things, they use data extractable from information on customers' public utility payments, the use of their loyalty cards, geospatial information, chat and voice transcripts, customers'

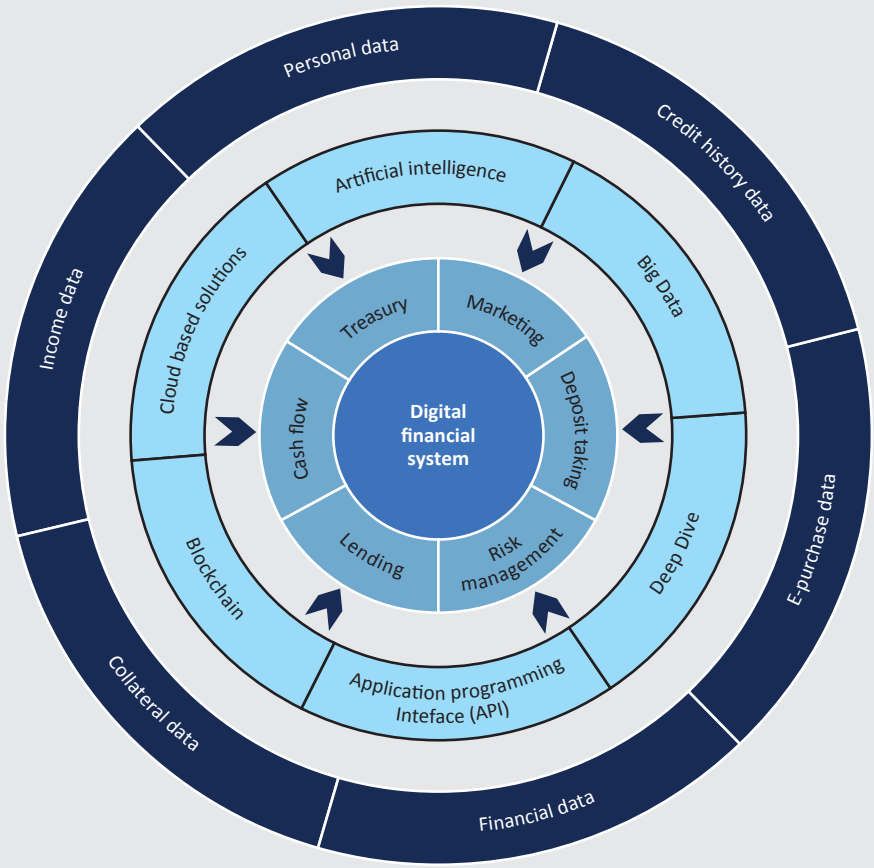
ratings, website visits and social media. By combining data sets in unique ways and with the help of machine-learning techniques, risk management methods can be further improved. Through a better segmentation of customers, the group of profitable loan customers and their related risk costs can be more accurately identified, and therefore customised offers can be created; furthermore, the total potential interest income might also rise. A more accurate identification of credit risk, by improving the portfolio, reduces the potential loan loss provisioning requirement, the capital requirement of lending and the loss given default (*Dash et. al. 2017*).

- *Fraud prevention:* With the advance of digitalisation and payments via online channels banking fraud and abuse has also increased:[1] On the basis of a survey by PwC in 2020, half of the responding institutions had experienced at least one fraud event over the past 24 months, which is the highest figure in the last twenty years. With the introduction of instant payment systems, financial institutions have less time to identify suspicious transactions and take appropriate measures. Finally, in recent years fraudulent incidents have become more complex, sophisticated and harder to detect (*Hasham et. al. 2018*). Parallel to increasing risks, it is important to develop the algorithms capable of preventing fraud and the data used by them, and put these on a 21st-century footing. With a targeted use of data and data analytics, by applying various developed, AI-based deep-learning algorithms, suspected fraud events can be more easily identified, and therefore trust in the financial system may increase and the operating risk of banks and their losses related to fraud may be mitigated.

Wide access to the data required for the digitalisation of banking processes may result in positive effects in terms of government and economic governance as well. Storing the income, employment and land registry data used most frequently by the financial system in a well-structured, widely accessible manner would contribute greatly to the simpler development and easier use of electronic government services. Digital data access may ease the workload of public customer services (e.g., tax office customer centres, government agencies, land registry offices), and the utilisation of data assets would even mean a new source of income for the state.

[1] https://www.pwc.com/gx/en/forensics/gecs-2020/pdf/global-economic-crime-and-fraud-survey-2020.pdf. Downloaded: 26 November 2021.

Figure 1
Technologies and data used by the digital financial system, and business areas using them



Source: MNB

3. International good practices

The financial sector is a typically data-dependent industry (*Nguyen – Paczos 2020*), with as yet untapped added value potential. Using and analysing customer data, data-driven business management affects practically all aspects of financial activities (lending, risk management, investment, fundraising, payments, etc.). Although these solutions are still rudimentary in the domestic banking sector, several successful business applications can be found at the global level.[2]

[2] https://thefinancialtechnologyreport.com/the-top-100-financial-technology-companies-of-2021/. Downloaded: 26 November 2021.

- *Buying insurance online:* Getsafe, a digital insurance company based in Germany, offers a wide range of insurance products – e.g. car liability insurance, dog liability insurance, drone liability insurance – in one single flexible application providing outstanding customer experience. The firm replaces complex, manual administrative tasks with solutions that also use artificial intelligence (smart bots) after transferring data available in the German car registry, allowing customers to file claims or change their coverage in real-time with just a few clicks.

- *Online SME lending platform***:** In Mexico, Konfio is the largest online lending platform in the country for SMEs. The firm uses the electronically accessible data of Mexico's tax office in their comprehensive digital lending processes. The fintech company provides online corporate loans of values between USD 100,000 and 3 million within 72 hours with the help of a proprietary algorithm, which carries out creditworthiness assessments within minutes.

- *Online lending and shopping platform:* Klarna[3] is a Swedish online e-commerce payment platform, which also offers instalment plans. Based on the account information available pursuant to the Second EU Payment Services Directive (PSD2) and customers' shopping and transaction history on Klarna's platform, Klarna immediately provides instalment plans for customer purchases (buy-now-pay-later, BNPL). As opposed to traditional consumer loans and credit cards, it offers free, immediately available financing to customers. The rise of online lending processes is also promoted by governmental initiatives which allow for online, electronic validation of borrowers' income. The Income Verification Express Service (IVES), operated by the tax office of Ireland, is a good example: with the consent of the borrower, the lender can submit a query to validate the income of the borrower in several different, electronically processable file formats.[4] Another example is the Canadian tax office, which provides also proof of net income of customers.[5]

- *Fraud detection:* Simultaneously with the expansion of instant payment systems, the fraud detection systems of banks also require development. As the speed of transactions has increased, the data volume to be processed immediately has also increased significantly, and it can no longer be managed and processed with the analytic methods applied in the past. The application of distributed file systems and computational solutions may help analyse very large volumes of data, for

[3] https://www.klarna.com/international/about-us/. Downloaded: 26 November 2021.
[4] https://www.irs.gov/individuals/international-taxpayers/income-verification-express-service. Downloaded: 26 November 2021.
[5] https://www.canada.ca/en/revenue-agency/services/e-services/e-services-individuals/a-proof-income-statement-option-print.html. Downloaded: 26 November 2021.

which for example Profinit,[6] a company based in the Czech Republic, offers fraud detection solutions developed for the financial sector.

According to a survey by McKinsey (*White et al. 2021*), wide-scale transition to data-based business models, increased access to data – in particular, financial data – may increase the credit-to-GDP ratio by some 20 basis points, via financial inclusion and supporting SME financing. In addition, the development of sales channels, a reduction in operating costs and more efficient allocation of capital may generate efficiencies of 5 to 50 per cent for banks, depending on their clientele, the data available and the composition of their portfolios (*Dash et al. 2017*). Thus, developing controlled, simple, electronic access to potentially available data assets can have a significant, direct positive impact on banking processes, which may be further enhanced by positive synergies (e.g. increased digital competencies and trust in digital services, etc.) affecting the economy as a whole.

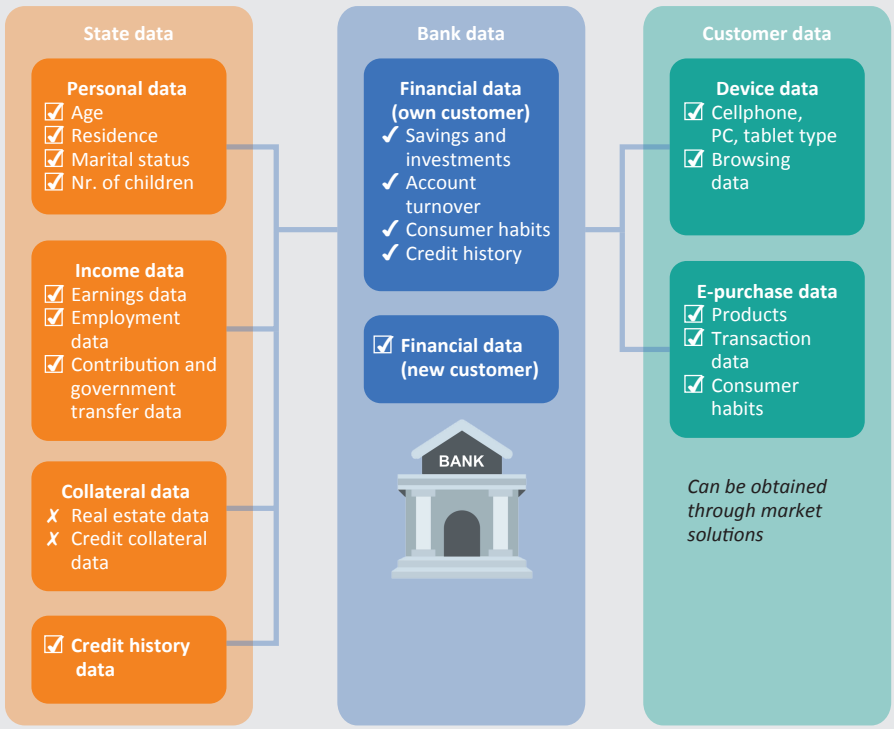
4. Situation in Hungary

In addition to data from their own customer bases, banks also heavily rely on customers' income and employment data, credit history data and collateral data. In connection with the green transition, the energy performance data of buildings and data on properties offered as collateral are also becoming increasingly important. However, the scopes of data required for the expansion of digital services are currently available from various data sources, are often fragmented, have different structures and island-like operation, and in many cases, electronic access is unavailable (*Figure 2*). The expansion of digital services is also hindered on the customer side by a still typical lack of trust in digital services and a lack of digital competences. Development of the digitalisation of the financial sector would be greatly promoted by creating access to electronic databases managed by the state. On the basis of their importance and international good practices, it is crucial to extend the range of data stored in the Central Credit Information System (CCIS) and ensure their availability irrespectively of client consent, to expand the clientele covered by the online earnings statements of the National Tax and Customs Administration (sole proprietors, licensed traditional small-scale producers and pensioners), and to ensure the up-to-date nature of data and the simplification of client consent. Furthermore, the efficiency of time-consuming and costly appraisal processes related to mortgage lending would be improved by the creation of a central database promoting the availability of automated, statistical property appraisal, while the expansion of green mortgage lending and the appearance of green mortgage bonds would be facilitated by banks' automatic access to the energy performance certificates of properties offered as collateral for the loans, stored by

[6] https://bigdataforbanking.com/success-stories/computing-anti-fraud-predictors/. Downloaded: 26 November 2021.

the Lechner Knowledge Centre (*MNB 2021*). Nevertheless, it is also essential that banks make their own databases available for external parties, and that the digital and financial education of clients, banking and public employees occurs.

Figure 2
Key data sources used by banks



Note: Based on current practice in Hungary, the data used by banks according to the availability of electronic access to them: ✓ – available; ☑ – subject to customer consent; ✗ – not available

Source: MNB

5. Conclusion

Connecting data comprehensively and a successful digital transition of financial service providers may significantly improve macroeconomic performance. With access to a wider range of data, banks can also increase the efficiency of their own business processes. This may increase the availability of financial services and enhance financial inclusion, and – at the same time – lower the costs incurred by both banks and customers. The state has a significant role in all this, on the one hand, as the manager of most data assets, and, on the other hand, as the entity responsible for the education that is required for the success of digitalisation processes.

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Mounting Challenges and New Horizons for the Banking System*

Ádám Nyikes – István Papp – Péter Sajtos

For centuries, banks have played an essential role in the functioning of the economy. However, the digital evolution of the 21st century has not only challenged the traditional role and operating principles of the banking sector, it has also created new competitors. What does the future hold for the financial system and financial services? In this article, we discuss three possible trends: (i) the emergence of a more efficient banking system; (ii) the spread of decentralised financial services; and (iii) the widespread adoption of central bank digital currency (CBDC).

1. Introduction

There are many different financial systems around the world, which differ significantly in terms of the historical context in which they were developed, their socio-economic environment, their sophistication and their regulation. The financial ecosystem has been and continues to be shaped by many factors, such as the spread of civilisations, changes in the needs of economic agents, extending deregulation of capital flows, industrial revolutions, the current wave of progress in information and data technologies, financial crises, changes in the regulatory environment and financial innovation.

While the way banking systems work on the surface has changed greatly over history, the core of how banks operate has remained almost unchanged until today. The central organising principle of commercial banking is that the liability side of the banks' balance sheets includes items (sight and other deposits) that are used as money by other agents of the economy. This allows banks to grant their loans in this liability, increasing their balance sheet total, while – putting it simply – they only need to provide liquidity to the extent that they remain liquid when deposit holders request a payment outside the bank.

* The papers in this issue contain the views of the authors which are not necessarily the same as the official views of the Magyar Nemzeti Bank.

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In the 21st century, however, the centuries-old hegemony of banks, shaped by two interrelated trends, has been challenged: on the one hand, the inherited "overbanked" structures are often too costly (*ESRB ASC 2014*), inflexible in resource allocation and inefficient in the era of digitalisation, and on the other hand, new, innovative players are trying to better meet ever-changing consumer needs, thus capturing some banking markets. Based on these trends, we try to outline a vision of how financial systems may evolve in the future.

2. Specificities of the operation of the banking system

Banks have long been key players in the economy and have successfully adapted to socio-economic and technological changes and transformations. In the past, financial innovation has often boosted the development not only of banks but also of the economy and society, and the sector has moved from being a follower and facilitator to being an innovator. As modern societies have developed, the use of banking services has become increasingly common, and banks have become an integral part of everyday life around the world. However, after the 2008 global financial crisis, banks lost their former role as innovators, and new innovative players emerged to become both partners and competitors to commercial banks. Rapid changes in consumer demand and technology are much more favourable for new, innovative players than for banks with traditional systems and business models, often based on decades-old knowledge.

Traditional banking systems now face many problems, partly due to their inherited structures. European countries typically have well-developed financial infrastructures, but too many banks and branches are expensive to maintain. This also affects pricing in many markets, with banks offering some services (e.g. payment services) at high prices, despite the fact that their services are far from customer-friendly in today's environment. However, banks derive a significant part of their revenues from the provision of payment services, and it is their centuries-old role in this area that was first challenged by new competitors. The new entrants' services include a range of innovative, fast, user-friendly and low-cost transaction services. These services pose a significant threat to the traditional markets of banks, even if they are not risk-free: some new products are unregulated, highly volatile and can be highly pro-cyclical.[1]

From a textbook perspective, the banking system performs its functions properly if it can withstand external shocks – not just environmental ones – and ensure the efficient allocation of resources on a continuous basis. There are many examples in economic history of banking systems operating in an unsustainable, pro-cyclical

[1] For more details, see: *Benk et al.* (*2018*)

manner, causing market turbulences or severe financial disruptions. Banking crises have serious economic consequences, resulting in significant costs for owners and sometimes for governments and customers as well. These negative instances have led to a societal demand for banks to operate in a sustainable way, i.e. not to take excessive risks, follow misaligned incentives or unsustainable business models. This is facilitated by the continuous evolution of the regulatory system.

3. Challenges for banking systems in the decade ahead

Nowadays, breaking up old structures in the financial system has also become more feasible, as the development of information and data transmission technologies has created large networks and customer bases around the world, making it cheaper and faster to spread information through global networks. The coming years could be a watershed moment in the fundamental functioning of our current financial system, changing not only our banking habits but, in extreme cases, the current logic and ecosystem of money creation and financial intermediation, based on bank lending.

Despite the aforementioned problems, such as low efficiency and allocation distortions, universal banks still dominate the financing of the economy in European countries today. This is partly because consumers in the EU are protected by strict data protection rules, which often act as a barrier to the introduction and spread of financial innovations. The degree of segmentation of the European market does not favour FinTech/BigTech companies. European commercial banks with well-developed financial infrastructures mostly started the digitalisation of banking processes based on developments of their own, thus lacking organic and well-functioning partnerships with FinTech/BigTech companies, which has led to a clear lag in the digitalisation of financial intermediation and innovation of new products.

In other parts of the world, the rise of FinTech companies is much more remarkable, for example in China, local FinTech/BigTech companies have played a significant role in the digitalisation of large banks, accelerating the digitalisation of banking processes and leading to productive collaboration between banks and these companies. In many African countries, the lack of financial infrastructure and the high cost of traditional banking systems have led to a surge in financial services provided by FinTech companies (*Eszes et al. 2018*). Technological progress provides a good basis for broadening the range of users of financial services and promoting financial inclusion. Technological advances in recent years – and the coronavirus epidemic of the past two – have brought significant changes to people's lifestyles, affecting banking habits and what is expected of banks.

Banking systems in Europe are also at a crossroads, and without radical efficiency improvements and service enhancements they will not be able to meet the demands of the times and withstand the increasing challenges of competitors. Digitalisation and digital operations are essential elements for the meaningful renewal of banks. However, digital solutions can only spread more widely and to less developed regions if the necessary conditions are in place.[2] Branch closures are particularly destructive where internet penetration and the digital literacy of the population are low. Thus, not only the financial sector, but also the government has an important role to play in the uptake of digital banking solutions. Traditional institutions that are not able to adapt to the digital needs of their customers may lose clients, and new players can take full advantage of this. FinTech/BigTech firms with their more technologically advanced, cost-effective solutions and customer-oriented services can become more attractive than traditional service providers. However, most FinTech/BigTech companies provide financial services without performing maturity and liquidity transformation. This essential operation is still carried out by banks, i.e. the dethronement of banks has not yet taken place, and commercial banks still maintain their market dominance almost everywhere in the world, but warning signs are seen more and more frequently.

4. Future development directions in banking services

It is difficult to predict the future direction of banking services, but three main trends can be clearly identified and analysed to guide us. The first of these trends is (i) the renewal of the banking system as we know it today, making it more efficient through digitalisation, in the spirit of sustainability. The next one is (ii) the spread of technology-based, decentralised financial platforms that can partially or fully replace today's financial intermediaries. The third development direction is (iii) the widespread adoption of central bank digital currency (CBDC), which could bring a transformation in the basic infrastructure of financial systems that would allow central bank money to innovate financial intermediation on a digital basis, while respecting security. For each of these trends, we present a general vision of the future, looking at three key banking functions (payments, lending and savings) in an attempt to map possible changes going forward.

[2] For more details, see: *MNB* (*2021a*): *Box 10, pp. 58–60*

4.1. Direction (i): a more efficient banking system

The renewal of the current banking system has already begun, with an increasing focus on technology in finance as well, with the development of digitalisation in banking, and it is already apparent that banks not participating in digitalisation could suffer a significant competitive disadvantage. However, there is still a long way to go before banking operations as a whole are placed on a new footing and a digitalisation-driven turnaround in efficiency occurs within banking systems.[3] On the customer side, the future of banking can be characterised by convenient, instant and fast digital services, accessible from anywhere. A more efficient service model built around the customer and a personalised, user-friendly banking experience in the digital space can increase customer satisfaction. The fact that customers will be able to access the internet – mainly via smartphones – almost universally in the near future can help achieve this.

All core banking functions on the client side may be significantly affected by this renewal. The combination of real-time availability, cost reduction and great customer experience – as the three main factors – in payments can lead to continuous innovation. The emergence of extensive digital interfaces and platforms for customers can provide a convenient way to access multiple services simultaneously and quickly, tailored to individual needs, while in the field of lending, the increasing amount of data generated by a growing online presence and the general evolution and integration of technology into credit decision processes can result in more personalised services and more convenient, fast and automated credit processing, which can be reduced to a few days or hours. In addition, the management of savings may also be affected by intense technological development, as improvements in search mechanisms and cost reductions can significantly automate portfolio decisions (e.g. robo-advice), while green and financial awareness products reflecting new perspectives can broaden the supply side.

At the same time, a modern operating environment is needed to achieve and maintain high, mostly digital, service standards. The institutions need to recognise that the potential of digitalisation goes beyond placing traditional processes into a digital space. The use of innovative, advanced technologies (e.g. deep learning algorithms, cloud-based solutions) in internal processes can be an important building block for a more efficient banking system. Innovative developments are enabling banks to move to a data-driven, digital operating logic, where the flexibility, speed and automation of processes brought by increasingly advanced technologies can reduce the amount of resources needed, time and complexity of processes, and lower operational and running costs. So, overall, there are substantial efficiency

[3] *MNB* (*2021b*): *pp. 10–14 and 16–19*

gains, while advanced solutions can provide better data management and better customer experience with a high degree of flexibility.

FinTech companies are also working towards a more efficient banking and financial system. There are numerous innovative solutions aimed at revitalising every element of the banking service and supply chain, embedded in financial intermediation to improve its quality and efficiency. In the wake of the coronavirus pandemic, particular importance has been attached to fully digitalised service delivery and it is expected to remain relevant in the long term. As a result, an innovative and digital approach and business logic will become an important basis for financial intermediation, where FinTech companies are currently leading the way. However, despite all these efforts, the relevance of commercial banking business models may still be crucial in an even more efficient financial system in the future: this is partly supported by the emergence and development of so-called neobanks. These new market players without a physical branch – typically FinTech start-ups – are also providing banking services to an increasingly wide range of customers. It is important to note that neobanks' business models – besides digital-only access – place significant emphasis on process modernisation and open ecosystem-based operation, thus supporting more personalised service delivery and the long-term success of efficiency improvement. In terms of improving customer experience, competition in the market is beneficial, and cooperation between incumbents and new players (neobanks, FinTech firms) can also lead to a better customer experience and has significant potential for systemic efficiency gains.

4.2. Direction (ii): decentralised financial services

In addition to making banks more efficient, rapid technological progress could make many financial services available in a peer-to-peer form, i.e. customers could carry out financial transactions directly with each other without the need for a traditional intermediary (e.g. a commercial bank for sending money or a stockbroker for investing). In these service delivery models, decentralised operation – without a central counterparty – can be based on the spread of technologies with increasingly transparent, unalterable data management mechanisms (e.g. blockchain), and on the automatic and algorithmic exploitation of the inherent value of data through active online presence. These factors could help the dissemination of applications and platforms based on the principle of decentralisation and the transition of financial services to a fully digital path, while further technological advances could also lead to a fully decentralised financial system (DeFi),[4] where technological bases that have emerged via blockchain and cryptoassets could completely eliminate financial or other intermediaries (e.g. stock exchanges).

[4] For more on this topic, see: *Katona* (*2021*)

Given that digital markets are open around the clock and around the world, the ability to operate without an intermediary could significantly support the real-time settlement of payment transactions. This model could also enable the automation of decisions related to more complex financial services, for example, various forms of direct lending can appear between users on digital platforms, where the lender and the borrower can meet, agree on terms and enter into a "contract" in the context of a personalised service. In addition, innovative solutions in the field of borrowing could also emerge, including the creation of large online investment communities where users can commit their free reserves without an intermediary in a transparent and traceable way, while the growing online activity and the dominant size of the online community could also act as a risk filter (e.g. by avoiding risky solutions in a group during crowdfunding).

Although the spread of decentralised solutions is already seen in some smaller market segments, the structures following the DeFi principle still carry several risks that could undermine the trust essential for long-term sustainable growth, even though many technologies already address confidentiality and integrity issues at an exceptionally high level. The potential reduction of the intermediary role may make it more difficult to deal with market imbalances (e.g. a shortage of resources if only borrowers appear on the platform and there is no one to meet the demand), while the lack of assumption of responsibility, and investor and depositor protection measures (e.g. complaints handling, dispute resolution processes, money laundering controls, deposit insurance), which is typically provided by the centralised actor, can pose a number of risks to consumers, and unpredictability can also pose stability risks to the financial system as a whole. Appropriate supervisory mechanisms could mitigate these risks, but the comprehensive regulation and ongoing supervision of constantly evolving and cross-border DeFi solutions is a significant challenge. In the DeFi framework, numerous financial services can already be seen that do not yet fit clearly into the current regulatory framework and defined types of activities, which present relevant challenges for both regulation and supervision. Against this background, while the potential of the technology is promising, the complete elimination of intermediaries is not yet a realistic scenario.

4.3. Direction (iii): central bank digital currency (CBDC)

CBDC has become an unavoidable topic for central banks in recent years, especially since the start of the coronavirus pandemic. The central bank digital currency is a digital form of money issued by the central bank in its own currency, different from traditional reserve or settlement accounts (*CPMI 2018*). Wholesale CBDC – i.e. CBDC accessible to financial institutions – could bring the reform of interbank and cross-border payments and settlement, while retail CBDC – i.e. CBDC accessible to the general public – could trigger the renewal of financial services and monetary

policy. Both types of CBDC would affect a slice of traditional banking operations, but the future of retail and corporate banking could be transformed primarily by the widely available retail CBDC.[5]

Two important factors are behind the rapid spread of the concept of CBDC. One is that central banks are increasingly concerned about the future of money, i.e. the question of what kind of financial currency citizens will use in the coming decades. If the national means of payment cannot meet modern requirements, the public may turn to other types of means that offer easy and simple payment in the digital space, which could lead to monetary sovereignty risks. The other important factor was the coronavirus pandemic itself. Although the digitalisation of the economy and society has long been an identifiable process, the coronavirus pandemic unexpectedly accelerated it. This has made the development of a central bank payment instrument compatible with the increasingly widespread digital payment solutions, even more topical.

The societal and economic impact of CBDC depends primarily on its design, which is why central banks need to set clearly defined strategic objectives when designing it. Such objectives can be to support digital financial inclusion, reduce market frictions and systemic costs, increase the efficiency of monetary policy, create a targeted stimulating tool or develop the financial services market by providing new innovative infrastructure suitable for the operation of smart contracts.

The emergence of the CBDC would not replace the current financial infrastructure, even in an ideal case, but as an alternative digital infrastructure it could represent a reform of the current financial system. Despite its complementary nature, it could have a significant impact on banking services and their development. In particular, it could bring changes in the area of payments, by offering citizens an easy-to-use, cost- and risk-free payment alternative that could be used in the digital space. At the same time, the role of financial intermediaries could be maintained by building additional innovative financial and complementary services around CBDC. With the CBDC at the core of the system, central banks could ensure interoperability between emerging financial platforms and ecosystems.

Depending on the strategic objectives and related planning decisions, a CBDC may also involve additional banking functions. Resources from deposits could flow to the central bank, which could raise financial stability issues. This process can be limited by the central bank through built-in mechanisms (e.g. restriction on the quantity held or adjustable interest rate). In some cases, a CBDC can also provide a credit function, allowing the central bank to effectively manage market frictions (e.g.: credit crunch, credit rationing). However, the intermediation role of banks

[5] For more details on the issues mentioned in relation to CBDC, see: *MNB* (*2021c*)

could be maintained in this case, similarly to other central bank lending programmes (see: Funding for Growth Scheme by the Magyar Nemzeti Bank, the central bank of Hungary).

5. Conclusion

Although banking systems as we know them today are confronted with mounting challenges considering the spectacular changes in the 21st century – such as rapidly evolving digitalisation and numerous sustainability issues – each of the three trends we have outlined presents an exciting vision for the future. Advances in technology can bring many useful innovations for customers, which may go hand in hand with a complete transformation of business logic as we know it today. However, based on what we know today, the most realistic scenario is that the dominant role of banks in financial intermediation will continue, as most FinTech/BigTech companies provide financial services without any meaningful maturity transformation, i.e. this key financial operation is still performed by banks. The other two trends – the transition to a decentralised financial system and the spread of CBDC – also have significant long-term development potential, and therefore the three trends are expected to develop jointly in the future. In this respect, the different directions may reinforce each other as they evolve, so that the financial services palette will not be limited to certain scenarios and types of institutions, but may open up new opportunities and horizons for sustainable development. The evolution of banking services is desirable and inevitable, but it should be remembered that the focus of this transformation must always be on the needs of customers.

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Crisis Chronology of the Past 100 Years*

Tamás Pál

Andrés Solimano:
A History of Big Recessions in the Long Twentieth Century
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Hungarian translation:
Nagy gazdasági visszaesések a hosszú huszadik században
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The period of roughly one hundred years after World War I can be considered a period of prosperity unseen before in the global economy. Unprecedented technological progress, rapid economic growth, significant accumulation of capital and comprehensive improvement in living standards weigh in one pan of the scale. However, this was not the result of any historical golden age or unbroken economic stability: in the other pan of the scale, the period was interspersed with destructive wars, conflicts between the Great Powers and financial crises. These not only led to volatility in output, but triggered hyperinflation, decades of stagnation in development and political turmoil in a number of countries. In many cases, the negative consequences affected whole regions or were even global. As the title itself also indicates, the past 100 years were far too long in the sense that economic downturns accompanied this period in great number and various forms. The book undertakes nothing less than a full inventory of the crises in the period with the thoroughness of a taxonomic classification, giving the reader a high-definition picture of the events. In doing so, it relies on comprehensive, but at the same time detailed and comparative data, examining a total of 744 recession events in 56 countries between 1900 and 2017. It provides an overview that systematises the crises in economic terms and analyses their reasons, courses and consequences. It is also a real treat for those who would like to better comprehend the developments by browsing the statistics.

* The papers in this issue contain the views of the authors which are not necessarily the same as the official views of the Magyar Nemzeti Bank.

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The book consists of nine chapters, including the Introduction. The first two chapters deal with crises, their causes, the differences in their courses and the possibilities of crisis management in general. Partly in chronological order, partly by region, broken down by groups of countries, the subsequent chapters discuss the major crises that typically affected several countries or regions or had global impacts. Accordingly, separate chapters are devoted to i) the hyperinflation of the two world wars and the 1920s; ii) the Great Depression of the 1930s; iii) the stagflation in the 1970s and the European problems up to and including the 2008–2009 financial crisis; iv) the crises in Greece and Latvia following that; v) the periods under socialism and following the political transformation in the post-socialist countries; and vi) the crises in Latin American and Far Eastern countries. The last chapter gives the reader comprehensive answers to questions regarding the consequences of crises, including, for example, their impact on inflation.

From time to time, crises hit unexpectedly, without any clear precursors. One need only think of the latest financial crisis or the one in Asia in 1997. However, there are problems not only with predictability. The causes are obscure after the event as well, or at least there are lingering questions. The main underlying reason is that it is not always a specific series of events that triggers a crisis: they result from the combination and complicated effect mechanism of various factors. One example for this that is presented by the author is that the path leading to the Great Depression in 1929–1933, which was the biggest crisis of the past century, has still not been thoroughly investigated. Firstly, its outbreak cannot be traced back to one country or one cause. Moreover, the role and importance of the factors subsequently named by economists are also controversial. Just think, for example, of the different explanations given by the monetarist or Keynesian approaches. While listing, on the basis of various opinions, what can be considered responsible for the emergence of the crisis, Solimano emphasises here as well that understanding the international context is of vital importance, especially if the crisis event is not limited to one or a few countries. Therefore, he presents in detail how complex the decade preceding the Great Depression of the 1930s was, and that it was made particularly complicated, inter alia, by the economic and political consequences of the world war, the return to the gold standard and the related monetary, exchange rate and balance of payments issues, the surge and collapse of the US financial markets as well as the agricultural crisis. Orientation is facilitated by properly selected and elaborated statistical data in this chapter as well, exploring not only the consequences according to various aspects (regarding, for example, output, industrial production, trade, prices), but also excellently presenting and rendering comparable the different impacts on the various macro regions and the seriousness of the crisis by country as well.

In light of Hungary's economic history of the past century and the 2000s, it comes as no surprise that Hungary is mentioned and discussed in several chapters, making the book particularly interesting for Hungarian readers from this aspect as well. Accordingly, Chapter 7 is especially worth highlighting. It deals with the events of the Soviet-type socialism and the transition, discussing in detail the situation of the European countries concerned under socialism, the transformation crisis of the 1990s and finally the 2000s until the financial crisis. Here again, appropriately compiled, ample data complement the analysis, which reveals not only the similarities but the differences as well. A remarkable lesson is to what extent the growth in the 2000s was driven by debt in Central and Eastern Europe. At that time, debt grew faster in a number of post-socialist countries than in the otherwise problematic late 1970s and early 1980s. Let us not forget that Hungary did not fail to accumulate debt in any of these periods, and as in the early 1980s, Hungary ultimately needed the IMF's help in 2008 as well.

In addition to the fact that we may find many more points of interest interpreted by the author, an important aspect of the book is that during the practical overview of this long period we can review our conception and knowledge of crises in general as well. The work identifies a number of factors that may lead to economic downturn. Although all of them are known, the book allows the crisis events to be catalogued based on these factors. It is to be noted, however, that unfortunately the scope of causes belonging to the external impacts needs to be expanded due to the Covid pandemic.

We can also learn much about the frequency and intensity of crises from the abundant data provided. If we look at the past 100 years, around 10 per cent of the economic recessions turned into crises. In the first half of the century, a higher ratio of economic recessions grew into crises. In the second half, this ratio declined, while the number of cases of economic recessions increased. Actually, the decrease in the ratio of serious events is not surprising, as it shows that we have learnt a lot from the experience of previous crises. At the same time, in the author's interpretation, the increase in the frequency of recessions, which was observed starting from the 1970s in particular, was concomitant with the deregulation and globalisation of financial markets.

While he descriptively points out the fact that the severity of a crisis may be exacerbated by an inadequate economic policy response, the author also underlines that, in spite of an increase in our crisis management knowledge, accepted and proven economic policy measures of crisis management also have their constraints. The necessary fiscal expansion easily conflicts with the sustainability of debt servicing or becomes unviable because of it. In view of their dependence on foreign capital, developing countries may be especially vulnerable in this respect. This is why the IMF's policy, which put priority on fiscal tightening in the case of countries

that got into trouble, taking fiscal sources from the restoration of economic growth and thus pushing them into protracted stagnation, may also be criticised. Last time, the related tragic consequences were seen in the euro area, in Greece. In terms of monetary policy, in line with the triviality of the monetary trilemma, the author considers the fixed exchange rate regime to be the main constraint, which prevents effective action for recovery from being taken. In addition, he also mentions the frequent problem that the deflationary pressure of crises renders sufficiently strong monetary easing more difficult. In general, however, he is permissive in the sense that the inflationary risks of monetary easing and the ensuing costs are exceeded by its results and benefits during a crisis.

Recently, more attention has been focused the so-called hysteresis effects, which means that a protracted recession or crisis may entail a permanent slowdown in economic growth. Solimano also notes that – contrary to a temporary downturn – recouping the macroeconomic loss may not occur after a lasting recession. While he can see these possible long-term negative effects of economic crises, the author considers the chances of fiscal and monetary policies very limited under the present circumstances, projecting a pessimistic picture for the near future. At the same time, in his closing thoughts, he believes that both economics and economic policy practice are shifting in the direction that the role of the managing of excessive indebtedness, financial market imbalances and future inequalities should receive greater attention. Nevertheless, we are now the ones who have to draw the final conclusion: more efficient defence by the state against the emergence of financial instability and excessive economic inequalities may have a positive impact on the frequency and severity of crises as well as on the possibilities of their management. Accordingly, a change in economic policy in this direction may also improve the future prospects related to crises.

Solimano's work is a great aid to orientation in the confusing history of the past century of crises. In addition to his interpretations, the book is made especially recommendable by the collection work and systematisation as a result of which we can examine crises through very detailed figures as well. The book is recommended for all who want to learn about specific major crises as well as for those who are interested in the comparison of crises.

Eurasian Patterns for a Sustainable and Digital Future – Report on the Budapest Eurasia Forum 2021*

Marcell Horváth – Dávid Szabó – Eszter Boros

What is the secret of the Asian technological successes of recent years? How can the West and the East learn from each other in the fields of innovation and investment promotion policies? What role do central banks play in the digital and green transition of the financial system? How does digitalisation affect the education sector? What are the major challenges to growth in the world economy? What future does Eurasian cooperation face in the century of a transforming world order? Last year's Budapest Eurasia Forum, a conference held annually by the Magyar Nemzeti Bank (the central bank of Hungary, MNB) since 2019, sought answers to these and similar questions. The event was organised as an e-conference on 18 and 19 November 2021, attracting more than 15,000 viewers.

The Forum examined the opportunities for Eurasian cooperation in relation to the prevailing megatrends of our day, with contributions from world-renowned experts. Topics included the rising role of geopolitics, the challenges and opportunities related to digitalisation, long-term sustainability, the revolution of money, the issue of central bank digital currency, and the opportunities stemming from the combination of these factors. The Forum explored these issues in six thematic panels again, presenting the latest trends in finance, economics, geopolitics, multilateral cooperation, technology, infrastructure, connectivity and education. Best practices and post-pandemic solutions were discussed by more than forty European and Asian experts, high-ranking economic policy and business decision-makers within the framework of wide-ranging presentations and panel discussions, making way for a novel, holistic, 21st-century approach and thinking.

* The papers in this issue contain the views of the authors which are not necessarily the same as the official views of the Magyar Nemzeti Bank.

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We are living the era of Eurasia

As in previous years, the central thread of the various topics was the rise of Eurasia. This is a long-term, non-linear process which involves dynamic rivalry, interaction and cooperation of the various economic and power hubs of the world, such as the Atlantic Alliance, East Asia, etc. Especially– but not exclusively – in the wake of China's strengthening, it is justifiable to speak about the birth of a new large power hub within this framework. In fact, we have arrived at a new stage of a comprehensive historical process: basically, the centre of gravity of the world economy has always been shifting within the Eurasian supercontinent: it moved an east-west direction over the last five hundred years and has now pivoted back towards the east. Regarding global investments, the expansion of eastern countries over western ones is increasingly obvious: in 2020, 70 per cent of global investments were already provided by eastern states, while 15 years earlier this ratio was 20:80, in favour of the West. This change can be also illustrated by Hungary's example: 2019 was the first time that the largest investor in Hungary was not Germany or another western country, but rather South Korea. This trend continued in 2020, with the Asian giant, China taking the lead. Furthermore, Hungary was the first EU Member State to sign a memorandum of understanding on the Belt and Road Initiative (BRI).

It is also important to pay special attention to the countries of the East, because according to Bloomberg's forecast, by 2035 China will have overtaken the United States to become the world's largest economy; the Economist expects this to happen in 2032, and according to bolder estimates, this turnaround may even take place before the end of the 2020s. In the age of economic, financial, technological and geopolitical transformation, we must remember the role of South Korea, Singapore, Dubai, Kazakhstan and Russia as well. A new economic and power hub is developing around China in narrower and broader concentric circles. The notion of Eurasia dates back at least 150 years and is present in both Western and Eastern political thinking. The notions of Eurasia of Anglo-Saxon geopolitical thinkers and Russian, Kazakh, Turkish and Chinese political philosophies were born against different backgrounds and in different ages, but there is a clear common theme: thinking in a broader Eurasian space.

Thus, the MNB's Eurasia Forum builds upon a living geopolitical-economic tradition. It intends to continue this tradition by strengthening the dialogue between the countries of the supercontinent, seeking common responses to economic, financial and social challenges, and presenting good practices. Furthermore, the aim of the event is to emphasise the special role of East-Central Europe, Hungary and Budapest. The existing parallel relationships with Western and Eastern civilisations

form a part of Hungary's historical heritage, representing extraordinary value in the light of the emerging multipolar world order.

Keywords of Prosperity in the 21st Century: Sustainability and Digital Development

In 2021, the event bore the title 'Sustainable Recovery and Prosperity in Eurasia – Trends, Future, Solutions', referring to the importance of innovation, multilateral cooperation and sharing 'good practices'. The Eurasia Forum is a unique conference organised by a central bank in Europe, because, on the one hand, it presents an unusually broad spectrum of economic-social life, and, on the other hand, because the participants are also special. The conference was opened by *György Matolcsy*, Governor of the MNB, *Péter Szijjártó*, Hungary's Minister of Foreign Affairs and Trade, and *Zhenmin Liu*, United Nations Under-Secretary-General for Economic and Social Affairs. *Guoli Tian*, Chairman of the China Construction Bank, which recently opened a branch in Hungary, was also among the distinguished speakers at the opening ceremony. Each year, many European and Asian experts who can be rarely heard together at a live event by the professional audience meet and exchange ideas at this conference. In 2021, Hungarian viewers had the opportunity to draw on the thoughts of *Gang Yi*, Governor of the People's Bank of China, *Parag Khanna,* a bestselling author and expert on geopolitics of Indian origins, and *Sopnendu Mohanty,* Chief FinTech Officer at the Monetary Authority of Singapore, while the remarks by *David Marsh,* Chairman of the Official Monetary and Financial Institutions Forum (OMFIF), *Paolo Borzatta,* a strategy consultant from Italy, and *Mateusz Rykała*, Vice President of the Management Board of the Katowice Special Economic Zone, Poland, were of particular interest to the Asian audience.

The keynote speeches highlighted the importance of Eurasian cooperation, which plays a prominent role in the midst of such challenges as climate change and the issue of transitioning to a sustainable economy, from different aspects. *Governor Matolcsy* pointed out that the prosperity of the region could be best achieved by combining Eastern and Western patterns, and that the promotion of multilateralism would play a key role in this regard. In addition to governments, central banks – whose scope of activities had expanded significantly in recent years compared to the practice of the past 30–40 years – would also play an important role in overcoming the obstacles ahead of us. Central banks should plan for the long term and incorporate factors such as climate risks, for example, in their operations. *Mr Szijjártó* added that for the development of the region, it was of key importance that multilateral cooperation be based on mutual respect and understanding.

After the opening ceremony, European and Asian experts examined the most urgent issues of our age in thematic panels. The two-day programme began with a panel on finance, entitled *'The Role of Central Banks in the Wake of the Pandemic – Experiences Across Eurasia'.* The panel focused on sharing the most important experiences concerning the management of the coronavirus crisis and discussing the changes in the role of central banks. Renowned experts, including *Gang Yi*, *David Marsh*, *Sopnendu Mohanty*, *Alexander Morozov*, Director of the Research and Forecasting Department at the Bank of Russia, *Yang Su Park*, Director General at the Bank of Korea, and *Barnabás Virág*, Deputy Governor of the MNB, explored the major challenges faced by central banks. The experts agreed that after the pandemic, several factors, such as inflationary pressure and the expansion of central banks' mandates, make things more complicated for central banks. Governor Yi called special attention to the fact that in the future, coordination between fiscal and monetary policies may become more difficult. Mr Virág emphasised that in recent years, central banks had started to actively deal with the two megatrends of our age, sustainability and digitalisation: 86 per cent of the institutions are exploring the opportunity of introducing a central bank digital currency (CBDC), and the 'greening' of central bank activities can also be observed. The experts agreed that central banks would learn how to manage existing challenges successfully if they prepared for innovative solutions, but also learned from the experiences of history. Mr Marsh also added that a holistic mindset was essential for responding to future challenges.

After the topic of finance, questions concerning geopolitics were addressed as the changing geopolitical space holds new challenges as well as opportunities for the world. The participants of this panel explored the opportunities for Eurasian cooperation. In the panel entitled *'The New Era of Geopolitics in Eurasia'*, *Parag Khanna,* renowned expert on geopolitics, *Norbert Csizmadia*, President of the Board of Trustees at Pallas Athéné Domus Meriti Foundation, *Rana Mitter*, Director of the University of Oxford China Centre, *Roza Nurgozhayeva*, Former Vice President of Nazarbayev University in Kazakhstan, *Huiyao Wang*, Founder and President of the Center for China and Globalization, and *Elena Rovenskaya*, Expert at the International Institute for Applied Systems Analysis, shared their ideas. According to Mr Khanna, by 2021 a new geopolitical approach will not only have covered extending influence over geographical regions but also the infrastructure running around and across them. Moreover, in the future the power struggle will focus on influencing the infrastructure of Eurasia. The states participating in the BRI can play a major role in reducing pollutant emissions, and China also has to make considerable efforts in this regard as well. Mr Wang noted that the green shift of the Belt and Road Initiative may also create new opportunities for China's allies in

Eurasia, to promote climate protection and the conservation of natural resources. Participants of the panel agreed that Eurasian countries would have the chance to manage emerging climate protection and social issues only in close cooperation, and therefore – with developing infrastructural opportunities– the pursuit of free and open dialogue should also be strengthened between Europe and Asia (and within the latter, China in particular).

Today, infrastructure, technology and connectivity are ubiquitous and exert a significant impact on almost every discipline, including finance, economics and education. Therefore, the Budapest Eurasia Forum dedicates a panel to this issue every year. The panel *'Infrastructure, Connectivity and Technology: Innovation is the New Normal'* explored the question of how digital infrastructure contributes to economic and social resilience. In this discussion, *Christopher Mattheisen*, General Manager of Microsoft Hungary, *Justyna Czyszek*, Vice Director of the Investor Support Department of the Kraków Technology Park Special Economic Zone, *Glenn Diesen*, Professor at the University of South-Eastern Norway, *Radosław Kedzia*, Vice President of Huawei CEE & Nordic region, *Sixuan Li*, Founder of ViaVia Shopping and Financial Commentator at CCTV Business, and *Péter Fáykiss*, Director of Digitalisation at the MNB, discussed the most important questions concerning infrastructure. Mr Mattheisen referred to the fact that digitalisation had accelerated due to the coronavirus pandemic, and thanks to technological advancement, we had such enormous volumes of data available as never before. The participants of the panel discussion also added that we were living the era of the Fourth Industrial Revolution, the main three pillars of which were 5G, artificial intelligence and big data. There was a consensus that, relying on these technologies, significant breakthroughs can be achieved in all areas of life in the future. It is also important that digitalisation should equally reach the population and market players. Mr Kedzia aptly called for 'being part of the change instead of waiting for the change'.

The second day of the conference began with a panel on the economy, with the title *'Innovation and Investments in Eurasia: Recent Best Practices'.* In the discussion, participants addressed important questions, such as the key factors of successful innovative activities, and why Eurasian tech companies have achieved enormous successes in recent years. *Qiang Ni*, Vice Governor of Hainan Provincial People's Government, *Paolo Borzatta*, Member of the Board of The European House – Ambrosetti, *Mateusz Rykała*, Vice President of the Management Board of the Katowice Special Economic Zone, *David Zeng*, Director of Corporate Affairs at Merck Holding (China), *Zongxian Feng*, Professor at Xi'an Jiaotong University in China, and *Dániel Palotai,* Executive Director of International Monetary Fund, took part in the panel. At the beginning of the panel, Mr Ni emphasised that the Budapest Eurasia

Forum had evolved into an important platform of dialogue which helps to seize the opportunities offered by Eurasian cooperation. As critical factors, experts identified the size of the available markets and the interaction of numerous and diverse, experienced professionals (for example through the network of universities and educational institutions), long-term educational and (basic) research investment, as well as government incentives and the self-organisation of companies. Mr Feng pointed out that, from the perspective of China's innovation and economic successes, special economic and free trade zones, aiming for increasingly high standards of regulation and services, played an important role. In connection with that, Mr Zeng said that for foreign companies (including Germany-based, globally active Merck Group), it was of key importance that they should fit the Chinese economic and innovation ecosystem and coordinate their activities with the directions of China's economic policy. All participants regarded cross-border cooperation as essential.

Panel 5 of the Forum was entitled *'Green Cooperation and Green Multilateralism – Sustainable Ways to Handle Global Threats'.* Its central theme was exploring the role of development banks and multilateral institutions in the green transition and the formation of regional and global partnerships with the aim of implementing green projects with long-term sustainability. In the discussion, *Simon Tay*, Chairman of the Singapore Institute of International Affairs, *Lin Cheng*, Director of Center for International Collaborations of the Beijing Institute of Finance and Sustainability, *Asel Nurakhmetova*, Advisor at AIFC Green Finance Centre, *Wenhong Xie*, Head of China at the Climate Bonds Initiative, *Linda Zeilina*, Founder and CEO of the International Sustainable Finance Centre, *Csaba Kandrács,* Deputy Governor of the MNB, and *Tamás Baranyi*, Deputy Director of the Institute for Foreign Affairs and Trade, exchanged their thoughts on the importance of green multilateral cooperation. According to the experts, the transformation of infrastructure is a key issue, and the required financial support should be available for the countries, in which different financial institutions must provide help. Mr Tay agreed with the importance of so-called green cooperation and stressed the need for the commitment of leading economies to global cooperation and the green transition. The experts claimed that the costs of certain green financial instruments should be decreased so that they could be used more widely and under much more favourable conditions. Mr Xie called attention to the fact that, while China is still on the path of catching up and addressing shortfalls compared to developed countries, it plays a leading role in green finance. All of the experts agreed that all countries and economic regions have their own plans for climate protection and the development of a sustainable economy, but international cooperation should be sought to implement these at

the global level. Ms Nurakhmetova remarked that financial institutions would play a key role in these processes.

The closing panel of the Forum, *'New Skills for a Digital Age – The Increasing Role of Digital Literacy',* examined the effects of globalisation from the perspective of education, with a special focus on the development of digital skills. The main topic of the panel was the effects of the rapid digitalisation process, and the role of universities in developing digital competences was also discussed. In this panel discussion, *Zhimin Chen*, Vice President of Fudan University in Shanghai, *Paul Cheung*, Director of the Asia Competitiveness Institute and Professor at the National University of Singapore, *Sang-Hyun Jang*, Director of the Korea Education and Research Information Service, *Sandra Kučina Softić*, President of the European Distance and E-Learning Network, *Timothy O'Connor*, Director of the Center of Competency at the National University of Science and Technology in Russia, *Levente Horváth*, Director of the Eurasia Center at the John von Neumann University, and *Kristóf Lehmann,* Director at the MNB, shared their thoughts on new trends in education. The experts agreed that the rapidly developing sector of digital education continuously posed challenges for educators and institutions, and therefore the attention of students should be attracted, using new platforms, techniques and innovation. Messrs Jang and O'Connor drew attention to the fact that teaching big data and artificial intelligence will take on a prominent role in the future. As Mr O'Connor added, in addition to the development of a digital skillset, teaching and developing indispensable basic communication skills, such as interpersonal communication, literacy, media awareness and a critical assessment of the sources of information also require greater emphasis. Mr Cheung's comments highlighted the major challenges to the future of the education sector: 'e-learning is simple, hybrid learning is simple, but how can we make adult employees learn new skills and adapt to the new economy? This is the really hard task!'

The key messages of the Forum were summarised by *Mihály Patai*, Deputy Governor of the MNB. The two-day conference shed light on the dominant role of strengthening the Eurasian partnership in addressing the challenges ahead of us, such as climate change and the promotion of inclusive, sustainable growth. The opportunities offered by the development of digital and cross-border infrastructure create a mutually advantageous situation for the development of the countries in the region. In the turbulent times that we now face, the most important task is to create balance, innovation and harmony in finance, economics, geopolitics, multilateralism, infrastructure development and education. The fusion of Eastern and Western models is indispensable for creating a prospering Eurasia.

The event helped place Hungary on the 'radar' of the Eurasian community: it was possible to watch the Forum live on the website of the conference (https://mnb.hu/eurasia), as well as on YouTube and Zoom. Participants could also take a newly published volume of studies 'in their hands', as the MNB made its unique collection entitled '*Age of Eurasia – Future Directions of Knowledge, Technology, Money and Sustainable Geoeconomics'* available online on the first day of the conference. Renowned experts not only from Hungary but also from China, South Korea, Singapore, Russia, Norway and the United States of America were involved in the creation of this work, published for the first time.

Report on the Symposium 'Coping with New (and Old) Vulnerabilities in the Post-Pandemic World'*

Mária Bábosik

A high-level international symposium entitled *Coping with new (and old) vulnerabilities in the post-pandemic world* was organised by the Global Partnership for Financial Inclusion (GPFI) on 4–5 October 2021, at the time of the Italian G20 Presidency, and hosted by the Italian central bank (Banca Centrale Italiana, also known as Banca d'Italia). The aim of the symposium was to evaluate the work carried out by the GPFI in 2021 and present experts' opinions on how to leverage digitalisation in order to leap forward in terms of financial inclusion, while limiting the risks of exclusion related to digitalisation itself. In view of the pandemic situation, the symposium, which could be followed on YouTube as well, was held partly with personal and partly with online participation. The Queen of the Netherlands was the guest of honour of the symposium. The introductory remarks were given by the Governor of Banca d'Italia on the first day and by the Minister of Finance of Italy on the second day. In addition to them, leaders and experts from major international organisations, top-ranking universities and research institutions shared their thoughts and experiences during the presentations and panel discussions, in the three sessions of the symposium.[1]

The symposium was opened by *Her Majesty Queen Máxima of the Netherlands*, as the United Nations Secretary General's Special Advocate for Inclusive Finance for Development and GPFI Honorary Patron. She expressed her happiness that today's technological innovations allow significant improvements in individual living conditions, and better living standards can be created for wide social groups as well. Nevertheless, she highlighted that the crisis affected the various social groups differently, and recovery from the crisis is taking place very unevenly. She stressed that the pandemic mainly affected women, people working in the informal economy, individual farmers and small businesses, whose access to the digital economy and financial services had already been limited prior to the crisis as well. In her opinion, the countries that had invested in digital public goods already before

* The papers in this issue contain the views of the authors which are not necessarily the same as the official views of the Magyar Nemzeti Bank.

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[1] For more details see: https://www.gpfi.org/news/high-level-international-symposium-0. Downloaded: 12 December 2021.

the crisis really experienced its benefits during the crisis. It allowed for rapid social transfers to those concerned as well as digital financial services and the spread of online payment. Digitalisation entails a number of challenges as well. It does not terminate inequalities, and may even exacerbate them, which can be offset by boosting financial literacy and strengthening consumer protection. Finally, Her Majesty welcomed the efforts of the GPFI, which foresee more digitalised finances that provide wider access than now, simultaneously with a reduction of digital risks. She is convinced that concerted actions will result in a successful recovery from the crisis and the creation of an inclusive, resilient and responsible digital financial system, which provides new opportunities for everybody.

The keynote speech of the first day was held by *Ignazio Visco*, Governor of the Bank of Italy. He considered the subject of the symposium extremely important, because as a result of the rapid spread of digitalisation the pandemic created new points of vulnerability and also amplified the old ones. He indicated that the issue of vulnerability had been dealt with by the G20 as well, when the Ministers for Innovation and Research met in Trieste on 5 August 2021 to promote dialogue on the digital transformation of the economy and society as a driver for a flexible, sustainable and inclusive recovery. In his opinion, it is necessary to prevent digitalisation from creating new forms of exclusion from financial services, and it needs to be ensured that the advantages stemming from digitalisation are enjoyed by the widest possible range of stakeholders. The spread of digital financial services creates new opportunities, meaning new threats as well at the same time. Unequal access to financial services may deepen social division, and in order to avoid that, it is necessary to develop digital infrastructure and access. The common target is 'not to leave anyone behind'. It is necessary to fight against financial exclusion and irresponsible financial behaviour. That requires two complementary measures: enhancement of digital financial literacy and competencies, as well as more innovative regulation and supervision. The recommendations developed by the GPFI present the best practices regarding both measures, whose aim is to create a financial system that ensures wider access. The presentation was concluded by drawing three lessons: during the fight against such a deep crisis, the long-term consequences of the policies applied need to be taken into account, and it is necessary to strive to increase financial literacy; digitalisation should and could be used as a stepping-stone to the extension and easing of access to financial services; and the threats of financial exclusion and the most vulnerable should be dealt with.

Following the opening speeches, Session I addressed *the impact of Covid-19 on financial inclusion*.

First, *Leora Klapper*, leading economist of the World Bank, presented new phenomena evolving as a result of the pandemic. She mentioned digital disbursements by the state, digital payment at retailers, online shopping as well

as new opportunities and risks, including regulatory flexibility, installation of the necessary infrastructure, development of new products and the strengthening of consumer protection.

Following that, *Matthew Gamser,* Chief Executive Officer of the International Finance Corporation SME Finance Forum, spoke about the impacts of the pandemic on micro, small and medium-sized enterprises. Regulation, consumer protection and financial literacy gained key importance as a result of the pandemic. Concerning regulation, he pointed out that due to the pandemic every country introduced easing for micro, small and medium-sized enterprises, and digitalisation in these areas entails enormous opportunities as well as major risks. In addition, the role of non-bank financial institutions and financial institutions as well as FinTech partnerships in the life of micro, small and medium-sized enterprises has changed and increased, which makes regulators face completely new tasks.

The keynote speech of the first day of the symposium was held by *Raghuram Rajan*, Professor at the University of Chicago Booth School of Business, former Governor of the Reserve Bank of India, and was entitled *New prospects for financial inclusion in the digital era*. The pandemic revealed the importance of access to financial services, he said, as well as the gaps and achievements in the development and accessibility of digital infrastructure. He presented a number of advantages as well as drawbacks of the digital revolution. He noted that technological development simultaneously means an opportunity to widen the access to financial services and a threat of being excluded from them. Regulation also needs to be sensibly innovative and experimenting, and needs to take steps even in areas that we cannot yet understand completely (e.g. large digital platforms, data protection, cryptocurrencies, etc.). Because digitalisation is an inevitable process, which may widen access to financial services considerably if we are able to adequately manage its challenges.

The panel discussion entitled *Digital financial services and new forms of financial exclusion* following the keynote speech was moderated by *Andrea Brandolini*, Deputy Director General for Economics, Statistics and Research of the Bank of Italy. In his introductory speech, he attached great importance to the development of digital capabilities of the society, in which various factors play a role, including, inter alia, the infrastructure, access, knowledge and experience. Of the participants of the panel discussion, French economist *Thomas Philippon*, Professor at the New York University Stern School of Business, directed attention to the opportunities and challenges inherent in FinTech. In his opinion, FinTech increases competition in the financial sector, but it is a question whether it makes access to financial services easier. He thought that FinTech may help mitigate discrimination but does not stop it. *Rohini Pande,* Professor at Yale University, pointed out that women are still at a disadvantage in the economy and in terms of access to financial services.

As this is not eliminated by competition, she is convinced that it is necessary to take strong steps against discrimination against women in order to make the use of digital financial services accessible and easier for them as well. As a representative of a major international organization, *Jean Pesme,* Global Director, Finance, Competitiveness & Innovation of the World Bank highlighted that in the digital age, the lack or low level of digital skills – which is typical for women in many countries – can also widen the gender gap in finance. To avoid this, special attention should be paid to increasing women's digital and financial skills. The last speaker of the panel discussion, *Ratna Sahay*, Senior Adviser on Gender in the Executive Board at the IMF, emphasised that – in parallel with their indisputable advantages – digital financial services increase inequalities in terms of the degree of availability of means, access as well as digital and financial literacy, and they pose potential security and data usage risks, which can only be overcome by the cooperation of the public and private sectors.

Similarly to the first day, the programme of the second day of the symposium proved to be interesting and substantial. In his opening remarks, *Daniele Franco*, the Minister of Economy and Finance of Italy, referred to three subjects: the G20 Digital Agenda, access to digital financial services and the digital transformation in Italy. He pointed out that the G20 Digital Agenda adopted at the time of the Italian Presidency foresees the creation of an accessible, open, fair and non-discriminative digital economy, which is one of the most important factors that allow the achievement of the UN Sustainable Development Goals. As a result of the pandemic, new forms of exclusion from financial services appeared. Therefore, it is necessary to widen access to digital financial services. In connection with digital transformation in Italy, he mentioned that it is facilitated by significant aid provided by the government, in line with its plan for post-crisis recovery and strengthening resilience. Finally, he recommended that the advantages of digital transformation be exploited and the danger of exclusion from digital financial services be warded off.

The programme continued with the work of Session II, with the subject of *supporting financial resilience, inclusion and transformation through digital financial literacy*. The first guest speaker of the session was one of the 100 most influential women on the Forbes list, *Annamaria Lusardi*, Professor at the George Washington University School of Business, founder of the Global Financial Literacy Excellence Center, Director of the Financial Literacy Committee in Italy as well as Chair of the Research Committee of the OECD International Network of Financial Education. In her presentation, Lusardi drew attention to the fact that there is an urgent need to address households' financial vulnerability. Many Italian families were already financially vulnerable prior to the pandemic, the impacts of the pandemic were unevenly distributed across the social groups, the crisis affected women and young people the most, and financial literacy provided some protection to prevent the

financial effects of the pandemic. Therefore, it is essential to increase households' financial resilience. Households' financial position in Italy is already improving this year, but inequalities are growing. Digital technologies are coming into general use, which means great opportunities as well as serious risks. Sophisticated use of technology requires increasing financial literacy. Summing up, she concluded that the crisis provides an opportunity to rethink the future. It is impossible to return to the pre-pandemic state, she said, and financial security and prosperity should be created for everybody. This requires a long-term attitude and focusing on families, which will certainly pay off.

The other guest speaker of the session, *Flore-Anne Messy*, Head of Division at the OECD, examined the role of digital financial literacy in increasing financial resilience and the promotion of digital transformation. Based on two GPFI reports of this year, she presented the impact of the pandemic on the financial resilience of households as well as micro, small and medium-sized enterprises, and also the effect of digitalisation on the activities and operating profits of these enterprises. She stated that households, micro, small and medium-sized enterprises had not had sufficient financial reserves before the outbreak of the Covid-19 pandemic either, which impaired their not too strong resilience even further. Many of them started to use digital financial services during the crisis. As a result, they felt the negative impacts of the crisis to a lesser degree, and this had a positive effect on their activities and profits. She touched upon the advantages and challenges of using digital tools, and finally drew attention to the importance of a long-term approach in the digital age.

Session II was followed by an overview of the experiences of three countries, the USA, Brazil and India. *James Woodsome*, representing the US Treasury, referred to the importance of increasing financial literacy, and presented the related national strategy and committee work as well as the best practices. *Diego Cruz*, representing the Central Bank of Brazil, spoke about the rapid digitalisation of finances and households' adjustment to that, the vulnerable groups and the main factors of their vulnerability. *Shri Pawan Kumar,* from the Ministry of Finance of India, pointed out the determining role of digital infrastructure as public good in widening the access to financial services.

The next part of the programme, Session III dealt with *consumer and MSMEs protection and regulation beyond the Covid-19 crisis*. As the first guest speaker, *Jonathan Zinman*, Professor of Economics at Dartmouth College, expressed his opinion that at present the regulation is based on wrong assumptions as well as on an insufficient knowledge of markets and consumers. He called for a change and for building the regulation upon proper assumptions based on research. Then, *Miles Larbey*, the Head of the Financial Consumer Protection Unit at the OECD, presented a report prepared jointly by the OECD and the GPFI on the impacts of the pandemic,

government measures, the lessons learnt from the crisis management as well as efficient approaches.

Following that, the session presented the consumer protection measures introduced by regulators during the pandemic, reflecting the experiences of three countries, the United Kingdom, Indonesia and South Africa. *Richard Monks*, Director of Strategy of the Financial Conduct Authority of the United Kingdom, highlighted the importance of a rapid, flexible, solution oriented regulatory approach, which is different from the traditional one. *Yunita Resmi Sari*, Head of Logistics and Facilities Management Department of Bank Indonesia, listed the digital tools that were introduced by Indonesia to strengthen consumer protection, and pointed out the importance of synergies and cooperation between stakeholders developing and operating these tools. *Katherine Gibson*, Deputy Commissioner of the Financial Sector Conduct Authority of South Africa, emphasised the importance of data collection and presented some of the findings of consumer surveys conducted in South Africa. Summarising the work of the session, Chair *Magda Bianco* drew attention to the fact that there is a gap between the actual situation and the regulatory intention in the fields of consumer protection and access to financial services and called for closing this gap as soon as possible.

Concluding the symposium, GPFI Co-Chair *Magda Bianco* presented the recommendations of the G20 and the GPFI, which aim at increasing digital financial literacy and the protection of consumers as well as of micro, small and medium-sized enterprises.

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Manuscripts should be submitted in accordance with the following rules:

- The length of the manuscripts should be limited to 40,000 characters (including spaces) but a ± 50 per cent deviation is accepted. Manuscripts should be written in Hungarian and/or English.
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- Papers always begin with an abstract which should not exceed 800–1,000 characters. In the abstract a brief summary is to be given in which the main hypotheses and points are highlighted.
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Thank you!

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