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Bulgaria's Path to the Euro: The Role and Legacy of the Currency Board*

Charles Enoch – Anne-Marie Gulde

Bulgaria's monetary integration with Europe started with the creation of the currency board in 1997. This paper traces how hard constraints on central bank financing and money creation, combined with political consensus forged in crisis, restored credibility, helped to attract investment, and supported deep structural change and privatisation. Despite the early success, however, Bulgaria's trajectory from crisis stabilisation to EU accession in 2007 and eventually to ERM II entry in 2020 and euro adoption was unusually long, shaped by a combination of persistent pre-crisis imbalances, the global financial crisis and the resulting stricter post-crisis European prudential demands. While Bulgaria's monetary policy after the creation of the currency board was determined by the anchor currency, euro entry still brings additional gains, such as representation in ECB decisions, lower currency and country risk, deeper financial market access and reduced transaction costs, while remaining costs are mostly transitional. Monetary success, however, does not fully resolve Bulgaria's broader institutional and demographic challenges.

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1. Introduction

The common currency, the euro, is a hallmark achievement of EU integration. It visibly signals progress in institutional and economic convergence within the block, and all but guarantees forward-looking monetary stability. Fifteen years ago,

* 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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observers were questioning whether the euro itself would survive amidst turmoil in the financial sectors in southern Europe. Now the issue is whether it can be a reserve currency, on par with or even surpassing the role that the US has held for the past eighty years.

For new EU member states, acceptance of the euro is mandatory once economic and institutional conditions are achieved; for many countries this was an important objective and was achieved quickly, while some others continue to show reluctance.

Bulgaria expressed its desire to adopt the euro very soon after joining the EU. Its path has been longer than others', but its entry on 1 January 2026 as the 21st member of the euro area represented a substantial achievement for the country, and was a further sign of the euro as a magnet for economic and political integration.[1] Bulgaria had a currency board arrangement (CBA) starting in 1997, and the country's entry into the euro area also shows that a well-designed CBA can serve to underpin a country's transition to a market economy even in the face of periodic headwinds.

2. Bulgaria: the path to the currency board

In 1989, Bulgaria began a tumultuous transition to a market economy. The overwhelming challenges of operating a new market-based economy while the necessary legal, institutional and supervisory frameworks were yet to be built led to a complex, crisis-prone start.

The extrication of the monobank Bulgarian National Bank (BNB, the central bank of Bulgaria) from its commercial banking operations left it to focus on its central bank responsibilities, while the commercial banking sector was mainly covered by a number of state-owned banks, largely the former branches of the BNB as well as the financing arms of some state-owned enterprises (SOEs).

Difficulties, however, were building up. There was a high degree of bank concentration, with the five largest banks (four state-owned, one private) owning 60 per cent of total assets in early 1996, and with some banks regionally or sectorally focused ("pocket banks" of particular enterprises). Privatisation progressed very slowly. The BNB had almost no supervisory powers over the state banks, and exercised limited authority over the private banks. For a while, the banks' situations were concealed through the unrealised capital gains that the banks reported as the currency fell, but the system became increasingly fragile (*Kojschev 1996*).

[1] *Enoch* (*2021*) discusses different forms of inclusive EU integration, noting that agencies such as the European Systemic Risk Board include both euro area members and non-member states.

The situation in the banking sector deteriorated as the state enterprise sector continued to run large losses. These corporate losses, together with the absence of effective bankruptcy procedures and a lacking repayment culture led to non-performing loans (NPLs) exceeding 60 per cent at many banks (*Sugarev 1996*; *IMF 1996*). These were accommodated by increasing credits from the banks as non-performing loans continued to rise and by bail-outs by the government, leading to an increase in government debt. Insider lending was prevalent, and none of the state enterprises was structurally reformed or declared bankrupt.

The many losses at the banks led to payment delays, eventually freezing activity in many sectors. As a result, growth reversed in 1996, with a decline of over 6 per cent in activity in the first half of that year. Inflation accelerated, and the concomitant rise in interest rates proved devastating for enterprises and hence for the banks. In July 1996, annualised inflation rose to 165 per cent.

Transparency in the Bulgarian economy was relatively high, and there was public awareness of the dire straits of the banking system, with lines forming outside several banks as rumours spread about the failing health of the banking system. The IMF was providing extensive technical assistance at the time, but was becoming increasingly concerned.

The closure of two large banks, Mineral Bank and First Private Bank, and three smaller banks in May 1996 proceeded relatively smoothly, but fuelled concerns about the weakness of the rest of the banking system, and the assurance of Prime Minister Videnov that there would be no more bank closures was not viewed as being credible. The BNB struggled in court to close the banks it had deemed insolvent, and some continued to operate ("zombie banks"). There was a continuing flight of depositors to the State Savings Bank (SSB), which was the only bank with an explicit depositor guarantee. The declaration of a full guarantee across the banking system was not held to be credible, given the level of public indebtedness. In July 1996, the IMF approved a reform programme with the Bulgarian authorities, but it quickly went off track, due to the larger-than-expected decline in economic activity, lack of progress in the SOEs and general lack of confidence in the programme.

By November 1996, Bulgaria faced not only an economic and banking crisis, but also a political crisis caused by the victory of the opposition party in the presidential elections. Confidence in conventional economic reform measures had evaporated. Debt had risen to over 120 per cent of GDP. High inflation and interest rates, together with continuing declines in economic activity as well as the ongoing financial crisis, indicated a need for a substantial change in policy direction. By March 1997, Bulgaria's annualised inflation was above 2,000 per cent and the country was in full-blown hyperinflation.

There was therefore from at least the summer of 1996 an increasing interest in establishing a CBA for Bulgaria, particularly after the failure of the July 1996 IMF programme. A currency board, an arrangement which had been widespread during the days of the British Empire, had recently been introduced for the Baltic states and (less successfully) for Argentina.[2] The advantage of a CBA would be to constrain the monetary authority's ability to expand the money supply – meaning its ability to lend to banks and the government – to the size of the country's foreign exchange reserves. The expected immediate fall in inflation would bring about the critical reduction in interest rates that would be needed to reverse the ongoing economic decline.[3]

By the autumn of 1996, the IMF had decided that credibility of a renewed stabilisation programme was critical. It would therefore only support another programme if it was on the basis of a CBA, ensuring that the central bank's ability to lend to the government or the commercial banks would be abolished or severely restricted.

As discussions continued, Bulgaria went into full hyperinflation. The leva, which had been around 70 to the USD in autumn 1996 fell to more than 3,000 to the USD by year-end. The hardship for the population, especially those on fixed nominal incomes, led to large street demonstrations calling for a change of government. Prime Minister Videnov resigned office on 13 February 1997, and Peter Stolyanov, Mayor of Sofia, was appointed as interim prime minister. Opposition leader Ivan Kostov won the ensuing parliamentary election in May. Discussions went forward on the basis of establishing a stabilisation programme with a currency board.

Discussions on a currency board intensified. One important goal was to find a design that would provide credibility, while maintaining some limited lender-of-last-resort facility (see *section 2.1.*) to backstop the still-fragile banking system. While economically devastating, the hyperinflation facilitated designing the currency board, in that domestic monetary liabilities had been reduced significantly ("inflated away"), so that foreign reserves could cover domestic liabilities without restrictions. Eleven of the weakest banks had been closed, and there was confidence in the government's ability to stand behind the remainder as necessary. Probably most importantly, there was confidence – internally and externally – in the newly elected government.

[2] *Appendix 1* shows some of the other countries that have or have had CBAs.
[3] For a detailed summary of Bulgaria's banking crisis and the banking sector's role in the development of the hyperinflation, see *Enoch et al.* (*2002*).

2.1. Design issues in setting up the Bulgarian currency board

When setting up the Bulgarian currency board there were several important design issues.[4] The goal was to go for a system that was sufficiently transparent and credible in reining in monetary growth, while at the same time retaining some flexibility and allowing for limited intervention to avoid a further banking crisis. Three core decisions were essential:

- *Legal basis*: On 5 June 1997, the Bulgarian parliament passed the new law on the Bulgarian National Bank which established the legal basis and operational principles for the currency board. Enshrining a significant number of details in law ensured that any changes would require a transparent and possibly lengthy legal process. Importantly, the law retained the bank supervision department within the BNB, with emphasis given to the enforcement of the newly enhanced laws and regulations.

- *Organisational design of the central bank*: In contrast to a number of earlier cases (including initially Singapore and the Republic of Ireland as they emerged into independence), there was not to be a stand-alone monetary authority, mechanistically adjusting the monetary base to changes in international reserves, but rather the BNB would be retained, with both an "Issue Department" responsible for maintaining the CBA and a "banking department", where resources could be used to manage the monetary supply within the CBA constraints. The intent was to give the BNB some limited flexibility to provide lender-of-last-resort support to the banks, hence helping to ensure confidence in the banking system, and reducing the risk of overspill to the fiscal side in the event of bank difficulties.

- *Anchor currency*: One remaining issue was the choice of currency to which the CBA should be pegged. Choices elsewhere differed, with Estonia's CBA pegged to the Deutsche mark, Latvia's CBA to the composite SDR and Lithuania's to the US dollar. Despite outside pressure for a peg to the US dollar, Bulgaria's overwhelming trade links to Europe, in particular Germany, led to the adoption of the Deutsche mark as its peg. On 1 July 1997, the currency board was introduced linking the leva at 1,000 to the Deutsche mark. This also enabled a smooth transition to a euro peg when Germany adopted the euro.

[4] See also *Enoch and Gulde* (*1997*)

3. Regaining stability: from the crisis to EU accession

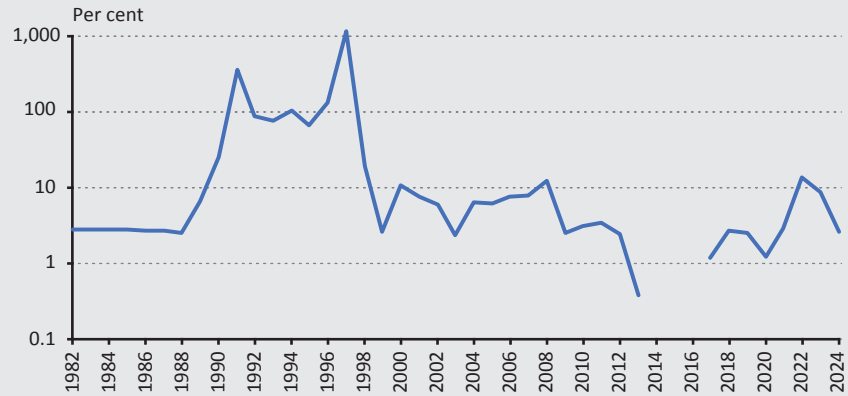
Transparency and expectations of the sustainability and durability of the planned CBA, particularly in light of the election of the new government in May 1997, led to rapid stabilisation once the currency board was announced, with stabilisation starting even before the regime was implemented. Once in place, inflation rapidly came under control, and interest rates fell accordingly. After continuing to fall for some months, economic activity started to recover. GDP rose by 3.5 per cent in 1998 after declines of 10.9 per cent and 6.9 per cent in 1996 and 1997, respectively. Inflation dropped from four digits to 22 per cent in 1998. Debt fell to less than half its pre-crisis levels (*Ghosh et al. 1998*; *Gulde 1999*). Foreign investment started to flood in, rising to over 20 per cent of GDP by 2007, with confidence further enhanced by Bulgaria's NATO entry in 2004.

Bulgaria saw deep changes in the ten-year period between the currency board stabilisation and joining the EU.[5] The IMF remained a major partner, and Bulgaria successfully completed three main Stand-By Arrangements during 1997 to 2007, with active programme involvement nearly continuous throughout the period. The IMF, World Bank, EU and bilateral providers also supported the country's institutional and structural reform through ongoing technical assistance (*IMF – World Bank 2003*; *IMF 2007, 2009, 2017*).

Following the crisis, the economy returned to substantial monetary stability and achieved solid growth: by 1999 inflation remained contained, but – as in other transition economies – it was mostly above the level of the anchor currency (*Figure 1*).[6] Real growth remained variable in the immediate aftermath of the crisis, but became consistently positive after 2000 (*Figure 2*), averaging 5.8 per cent per year between 2000 and 2007, which was particularly remarkable as the population fell by around 7 per cent over this period (mainly through emigration of people of working-age), thus generating an even larger increase in per capita income.[7]

[5] See *Bechev* (*2010*).
[6] The Maastricht inflation criterion for joining the euro requires that a country's inflation rate be close to the average of the three best performing EU members, meaning not to exceed that value by 1.5 per cent.
[7] Bulgaria's population fell throughout this period, but at a faster rate after 2007, declining in total from around 8.5 million in 1995 to 6.5 million in 2025.

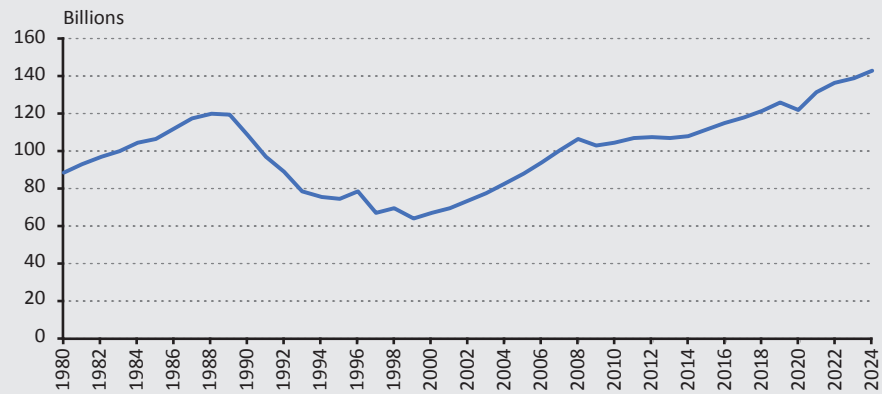
Figure 1
Inflation, average consumer prices (1982–2024)



Note: A logarithmic scale is used to illustrate the vast differences in inflation levels. Periods with negative inflation (deflation), specifically between 2014 and 2016, are not plotted due to the mathematical constraints of the logarithmic scale.

Source: IMF World Economic Outlook Database

Figure 2
Real GDP in national currency (1980–2024)



Source: IMF World Economic Outlook Database

The fiscal balance stayed strong throughout, with incomes policies ensuring that public sector wage growth stayed below that elsewhere in the economy. Public debt declined from nearly 70 per cent of GDP in 1998 to less than 20 per cent in 2007 (*Table 1*).[8]

Table 1
Bulgaria – Macroeconomic Developments (1997–2007)

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
GDP[1]	–14.1	3.8	–8.4	4.6	3.8	5.9	5.2	6.5	7.1	6.8	6.7
Per capita GDP[2]	12,743	13,319	12,259	12,692	13,608	14,491	15,336	16,420	17,675	18,974	20,340
CPI[3]	1,061.2	18.7	2.6	10.3	7.4	5.8	2.3	6.1	6.0	7.4	7.6
Fiscal balance[4]	n/a	1.1	0.2	–0.6	–0.6	–0.6	0.0	1.6	2.2	3.2	3.1
Government gross debt[4]	67.3	78.7	73.3	67.1	53.4	45.4	37.8	28.5	22.6	17.6	14.7
Current account[4]	13.5	1.1	–2.9	–3.1	–3.6	–0.6	–3.4	–4.3	–9.4	–15.3	–23.9

Note: [1] Per cent change; [2] International dollars, PPP basis; [3] Per cent change, period average; [4] Per cent of GDP. To ensure a sufficiently long and consistent time series for international comparison, purchasing power parity (PPP) data sourced from IMF.

Source: IMF WEO database

Deep structural changes led to a marked shift away from agricultural employment and a different ownership structure of banks and enterprises. By 2007, 75 per cent of the economy was privately owned, including 100 per cent of the banking sector. Capital markets started to develop. Bulgaria's per capita GDP on a PPP basis, which had been only 30 per cent of the level of the major EU member states before the crisis, reached 40 per cent in 2007.

3.1. EU membership, but lengthy efforts towards euro adoption

Bulgaria joined the EU in 2007, together with Romania in a bespoke membership process. The two countries followed an earlier group of Central and Eastern European Countries that had gained membership in 2004. More deep-seated structural challenges than these earlier entrants and, importantly, a different global economic environment led to a distinctly different membership path compared to the earlier entrants. Specifically, it was recognised that Bulgaria and Romania had not yet fully converged to all critical EU standards, which in the past had to be achieved by the time of membership. Nevertheless, acknowledging the importance of achieving membership, the EU took the view that the deep structural and institutional changes that were still needed could be achieved while the countries already were members.

[8] *Wolf et al.* (*2008*) discuss the performance of currency boards compared to other exchange rate regimes. Their results for a large panel show that countries with CBAs on average have lower inflation and better fiscal outcomes, but also lower growth. They emphasise that once stabilisation has been achieved, the challenge for a CBA would be to find a credible exit mechanism.

To ensure the necessary momentum, the EU instituted country-specific Cooperation and Verification Mechanisms (CVMs) for both countries. In the case of Bulgaria, this was based on a series of judicial reforms, as well as significant efforts to fight corruption and organised crime. Progress would be monitored through regular reporting, benchmarks and annual European Commission Assessments. Commitments under the CVM guided both the membership process and the key steps in Bulgaria's journey for sixteen years; following achievement of the stated goals, the CVM process was formally closed in September 2023.[9]

Table 2
Bulgaria – Key Macroeconomic Indicators (2006–2025)

	2006	2007	2008	2009	2010–2015	2016–2020	2021	2022	2023	2024	2025[4]
GDP[1]	6.8	6.7	6.1	–3.3	1.4	1.8	7.8	4.0	1.9	2.8	2.5
CPI inflation[2]	6.1	11.6	7.2	1.6	0.9	1.3	6.6	14.3	5.0	2.1	3.1
Import volume[1]	15.9	22.6	4.9	–21.5	4.8	3.7	9.0	13.6	–4.3	2.0	4.4
Export volume[1]	7.7	19.6	2.5	–11.7	7.5	2.1	8.2	8.3	3.4	–0.2	0.7
Current account	–15.3	–23.9	–22.1	-8.3	0.2	1.8	–1.1	–2.6	0.9	0.2	–1.5
Fiscal balance	3.1	2.2	1.0	–0.5	–2.2	0.1	–3.5	–1.4	–3.2	–3.2	–3.1
Government gross debt	22.6	17.6	14.7	14.5	19.0	22.2	22.4	21.5	21.9	23.4	28.0
Memo items:											
Per capita GDP[3]	13.2	14.6	15.8	15.4	17.8	23.3	29.7	35.1	37.0	39.4	41.9
EU average per capita GDP[3]	32.8	34.7	35.6	34.2	37.6	45.1	52.6	58.2	60.3	62.3	64.5

Note: [1] Per cent change; [2] Per cent change, end of period; to assess convergence criteria the ECB and EU use the European HIPC which can differ somewhat from CPI, due to compositional difference; [3] In thousands of international dollars, PPP based; [4] Estimate.

Source: IMF WEO database

After joining the EU, Bulgaria's government expressed strong interest in joining the euro area as early as possible.[10] To do so, the first step was to join the ERM II mechanism. ERM II is the EU framework to promote exchange rate stability and assess real convergence in preparation for euro adoption. To enter ERM II, an EU country's finance minister and central bank governor jointly apply. Exiting from ERM II into the euro is possible once exchange rate stability has been achieved and the Maastricht convergence criteria are met. The process requires that both the ECB and European Commission issue positive Convergence Reports, and existing euro area members together with the ECB must approve the country's entry into the euro area. ERM II is set for a period of at least two years and is often informally called the "waiting room for the euro" (*Appendix 3*).

[9] See *Appendix 2* for details on the CVM process for Bulgaria
[10] Economic analyses also supported the goal of early accession (*Yorgova 2011*).

Noting that other CEE accession countries with the intention of joining the euro had acceded to ERM II after a relatively short period after EU membership (*Table 3*), Bulgaria's finance minister expressed his hope to enter into the ERM II by 2009.[11]

Table 3
EU Accession Countries and ERM II time

Country	Date of EU membership	Date of entry into ERM II
Accession countries with expressed strong interest in joining the euro		
Estonia	2004	2004
Latvia	2004	2005
Lithuania	2004	2004
Slovakia	2004	2005
Slovenia	2004	2004
Bulgaria	2007	2020
Croatia	2013	2020
Accession countries which have not yet applied to ERM II yet[1]		
Czech Republic	2004	n.a.
Hungary	2004	n.a.
Poland	2004	n.a.
Romania	2007	n.a.

Note: [1] Outside of accession countries, Sweden is the only other member still to apply for ERM II.

Early optimism in Bulgaria about the speed of entry to ERM II as a first step to the euro proved premature. Given the widening macroeconomic imbalances around 2007 and with inflation significantly above the EU average and substantial current account deficits (see *Table 2*), a formal request to join ERM II at the time of membership did not look feasible. When the domestic situation stabilised, the global economy became an obstacle. With the euro area in crisis, sentiment about expansion in the European institutions clearly shifted to one of extreme caution.

The Bulgarian economy was severely impacted by the global financial crisis (GFC), but the authorities initially remained interested in quickly joining ERM II. Signals from the EU, however, were not supportive. Accordingly, the Bulgarian finance minister, following a meeting in 2009, revised earlier more optimistic announcements, saying that the process was going to take longer than expected.[12]

[11] On the monetary integration of the CESEE countries at that time, see (*Backe 2009*).
[12] https://www.novinite.com/articles/107615/Bulgaria+Finance+Minister+Takes+ERM+2+Application+to+Brussels+Next+Week.

Only in 2015 the government under Prime Minister Borisov shifted back toward a more active stance on euro adoption. To accelerate the process, the administration created a coordination council, headed by the Minister of Finance and including the BNB to develop a national roadmap. The high-level committee was supported by a group of technical experts to design the necessary legal and institutional changes called for by ERM II.

The EU and ECB were officially supportive, but the in the aftermath of the GFC there was a sense of caution, and concern that any decision needed to well-founded. The Bulgarian government and the relevant European counterparts discussed how to best address remaining concerns about institutional and structural issues, while allowing ERM II participation in the near future. To demonstrate its interest, in mid-2018 Bulgaria made prior commitments to be fulfilled before ERM II entry.[13] Pre-ERM II commitments on monetary issues (to be assessed by the ECB) included strengthening banking supervision, improving the macroprudential toolkit and transposing EU anti-money laundering directives into national law. A second set of commitments was to be assessed by the EU Commission and included improvements in supervision of the non-banking financial sector, adaptations to the insolvency framework and strengthening the anti-money laundering framework as well as the governance of state-owned enterprises.

On 30 April 2020, Bulgaria officially submitted documents showing the successful completion of the pre-ERM II accession commitments. As a result, the EU approved Bulgaria's accession and the country entered ERM II on 10 July 2020. Under a June 2020 ECB decision, Bulgaria also became a member of the European banking union under a close cooperation agreement, which entered into force on 1 October 2020 (*Dorrucci et al. 2020*).

Bulgaria entered ERM II with its currency board unchanged. In general, the exchange rate mechanism under ERM II allows for a member country's exchange rate to fluctuate within a ±15-per cent band around the central rate. Like for the previous currency board countries (Estonia, Lithuania and Latvia), Bulgaria was not expected to change its monetary arrangement and instead was able to retain its currency board arrangement.[14] Given the still strong memories of hyperinflation and the related popularity of the currency board, there had not been any serious discussion

[13] Croatia went through the same process at this time and agreed to a very similar set of pre-commitments. The EU institutions justified the need for pre-commitments given that the entry of these two countries into ERM II would be the first such move since the GFC, which had led to a general tightening of regulatory and prudential requirements.

[14] In the context of the Baltic currency boards, it had been decided that a membership applicant could retain a currency board during ERM II and floating in a band was not required. The issue was raised again in the context of Bulgaria before the European Commission and the ECB reaffirmed their earlier position. For applicant countries whose currencies are in the standard 15 per cent band during ERM II, the ECB and national central bank are expected to intervene if a currency hits the edge of the band; in the case of a currency board, however, where the country has adopted a much tighter band (i.e. zero), the ECB has no obligation to intervene to protect that band.

about changing the exchange rate regime in the context of ERM II. The central exchange rate of 1.95583 leva per euro with a zero band stayed in place, with the BNB remaining committed to full coverage of its reserves (*Coordination Council for the Preparation of the Republic of Bulgaria for Euro Area Membership 2022*).

3.2. Meeting the euro area criteria

Early hopes for a brief ERM II period did not materialise. Having entered the system at the very outset of the Covid-19 pandemic, inflation proved to be a major concern.[15] The 2022 biannual convergence reports by the ECB and EU Commission – issued in June 2022, just a month short of the minimum two-year ERM II period – found Bulgaria not ready to adopt the euro (*European Commission 2022; ECB 2022*). In part resulting from Covid-19, the budget deficit was above the 3-per cent reference value (as indeed it was for member states already using the euro). Inflation was also above the reference value, exacerbated by external shocks, and remained volatile, limiting readiness.[16] In addition, legislation – especially regarding central bank independence, monetary financing prohibition and ECB/ESCB integration – needed further alignment with EU legal requirements. Meanwhile, Bulgaria met other Maastricht criteria including on exchange sustainability, public finances and interest rates.

The regular 2024 report (*European Commission 2024; ECB 2024*) noted significant progress, but inflation remained above the reference value and the earlier hope of euro adoption in January 2025 proved unattainable. The report also noted, however, that Bulgarian law was now deemed compatible with EU requirements for euro adoption, subject to interpretations and ongoing vigilance.

In February 2025, Bulgaria requested an updated convergence assessment from the EU Commission and the ECB. The request followed the Eurostat release of inflation data which indicated that the country had met the price stability criterion, removing the last barrier to joining the euro area. On 4 June 2025, the 2025 convergence reports by the European Commission and ECB concluded that Bulgaria fulfilled the economic and legal criteria for adopting the euro (*European Commission 2025; ECB 2025*). The positive assessment set in motion all needed legal and institutional steps which were completed by early July (*Appendix 3*).

[15] For economic analysis regarding Bulgaria and Croatia fulfilling criteria, see *Walko* (*2022*).
[16] Convergence reports covering all EU members not participating in the euro are prepared on a biannual basis. However, countries are free to request special convergence assessments outside of this cycle.

Table 4
Bulgaria's Compliance with Convergence Criteria (Final Assessment)

Convergence Criterion	Key Indicator	Reference Value	Bulgaria (2025 Assessment)	Status
Price stability	12-month average HICP inflation	Based on best performers	Met the stability criterion	Fulfilled
Fiscal deficit	Net lending/ borrowing	≤ 3 per cent of GDP	Below reference value	Fulfilled
Government debt	Gross Debt	≤ 60 per cent of GDP	23.1 per cent[1]	Fulfilled
Exchange rate	Participation in ERM II	≥ 2 years	Member since July 2020	Fulfilled
Long-term interest rate	10-year government bond yield	Based on best performers	Within reference range	Fulfilled
Legal convergence	Central Bank legislation	Full compatibility	Deemed compatible by June 2025	Fulfilled

Note: [1] 2024 estimate

Source: Compiled by the authors based on the 2025 Convergence Reports European Commission (2025) and ECB (2025)

4. Euro membership

4.1. Benefits of euro adoption

With its currency board, Bulgaria had already captured some of the benefits of a joint currency with the main European partners. The euro, however, will bring a number of further benefits (*Enoch and Gulde 2025*), including the following:

- *Regaining a voice in monetary policy decisions*: As a member of the euro club, Bulgaria will for the first time participate in making monetary policy decisions. Since 1997, Bulgaria was indirectly affected by those decisions, but was not able to weigh in on monetary policy.

- *Reducing currency and country risk*: The euro, a reserve currency, will help to further reduce foreign currency risk. While Bulgaria's currency board was stable and legally anchored, other countries have exited currency boards, and hence there continued to be a degree of currency risk. Following the positive news on the upcoming euro adoption, several rating agencies upgraded Bulgaria (*Fitch Ratings 2025*; *Morningstar DBRS 2025*; *S&P Global Ratings – Fitch Ratings 2025*; *Scope Ratings GmbH 2025*), noting lower currency and country risk with Bulgaria's currency now part of a reserve currency. Euro adoption also demonstrates the international acceptability of the legal and institutional framework, supporting trade and investment due to lower country risk.

- *Supporting banking/financial stability*: Under the currency board, the BNB did not have an unlimited "lender of last resort" facility, which – in periods of extreme pressure – could have led to a liquidity crisis. As part of the euro, Bulgarian banks will have access to ECB facilities, making their liquidity supply in a crisis situation much more secure.

- *Participating in deep money and capital markets*: With euro adoption, Bulgarians will be able to directly tap into the deep euro financial markets. Euro members have more seamless, resilient and lower-cost access to euro capital markets, especially during periods of volatility, while non-euro countries can access these markets only through EUR-denominated issuance and usually trade at higher spreads.

- *Facilitating trade and travel*: Notwithstanding a fixed exchange rate, every foreign transaction required currency exchange, with costs in the range of 1 to 3 per cent of the transaction. The euro will eliminate these costs for all transactions with the rest of the euro area, which is Bulgaria's predominant trading partner. Deeper markets for the euro compared to the leva will also reduce transaction costs with non-euro currencies.

4.2. Expected costs: transitory versus structural impacts

Given Bulgaria's currency board, the economic costs of adopting the euro are limited. In general, adopting a regional money implies an end to a country's ability to make independent monetary policy decisions. Bulgaria, however, had already given up the ability to use active monetary policy with the adoption of the currency board and has not used active policy since. Once the country adopts the euro, monetary policy will continue to be made outside, but – in contrast to the currency board situation – Bulgaria will be part of the ECB Council and have some input on regional policymaking.

Other more tangible costs of euro adoption relate to the necessary operational changes for businesses and for the government. For businesses, this includes the need to adapt accounting systems, change denomination in contracts and retail price signs, and provide staff training. For the government, it entails reflecting the new currency in all laws and regulations. The impact on inflation is feared as a major cost, but in other countries this has been shown to be small and temporary.[17]

[17] This phenomenon has been widely studied. With regard to Germany, research found that the changeover from the Deutsche mark to the euro raised aggregate inflation rates on a one-time basis by about 0.05 to 0.23 percentage points, mainly due to rounding ("menu" costs) and pricing strategies for services such as catering and restaurants. Similar results were found for other countries; in all cases, the effect on individuals and groups was found to differ depending on their consumption basket, and in most countries inflation perception exceeded the actual increase in prices (see *Mastrobuoni 2004*; *Sturm et al. 2009, and Petrylė – Bunevičiūtė 2023*).

5. Summary and conclusions

Bulgaria was hit particularly hard at the outset of its transition towards a market economy, because of its heavy industrial legacy and lack of clear political commitment. By 1996, the conventional approach to economic transition seemed to have failed, as inflation was becoming embedded, public indebtedness rising and the government discredited. The descent into hyperinflation towards the end of the year made a radical change in strategy urgent.

The CBA met the needs of the moment. The scope for discretionary policies was severely constrained. Monetary expansion was limited to the size of the country's foreign reserves and gold holdings, and fiscal policy was constrained to be consistent with these restrictions. Legal passage of the CBA gave the arrangement credibility, and thus inflation expectations plummeted, and inflation and interest rates fell rapidly. After a period of economic slowdown growth resumed again. That said, some flexibility was built into the system, so there would be some scope to respond to economic shocks. Moreover, incorporation of the CBA within the BNB meant, importantly, that the institution regained credibility as the economy stabilised.

Economic pressures in the following years meant that Bulgaria experienced multiple changes of government. Nevertheless, memories of the pain inflicted by hyperinflation meant that the CBA was never seriously threatened. The economy was challenged by the emigration of 20 per cent of its population during this period, with this occurring largely among the marketable, younger population. On the other hand, the Bulgarian economy benefitted from remittances from abroad, which rose from zero in 1996 to around 8 per cent of GDP in 2003, as confidence in the new economic arrangements took hold, before dropping to around 3 per cent and staying at that level thereafter.

Bulgaria took time to overcome its many structural challenges, and thus it was not yet ready to enter the EU at the same time as many of the other transition economies. However, in 2007 after further reforms and agreeing to a post-membership monitoring process Bulgaria (together with Romania) achieved EU membership.

Bulgarian governments hoped to join the ERM II, the precursor to euro area membership, soon thereafter, as other transition economies had done. The following period, however, was characterised by a series of negative external events – the global financial crisis, the euro crisis, and Covid-19 – which knocked the Bulgarian economy off course and made the EU more cautious about widening participation in the euro. During this period, the purely economic case for the CBA was perhaps less clear – Romania grew faster than Bulgaria for much of the period between 2007 and 2020 – but the credibility of the CBA continued to underpin

economic stability, and the adoption of the euro would be the only feasible exit from the arrangement that would ensure this credibility would be maintained. As of 1 January 2026, this was achieved, and Bulgaria became the 21st member of the euro area.

Thus, the CBA served a critical role in 1997 at a time when alternative strategies had been tried and were seen to have failed. The memory of the pre-CBA hyperinflation was an important component for maintaining support for the CBA in the following decades. The limited flexibility in the non-traditional design of the CBA and the embedding of the CBA within the BNB added to the strength of the arrangement. Finally, the prospect of joining the euro area provided an end-point for managing the CBA and for the country's ultimate exit from it. The benefits of the euro area membership should further advance Bulgaria's economic progress.

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Appendices

Appendix 1: Some examples of currency board arrangements

Currency board arrangements (CBAs) have a long history as colonial monetary arrangements, but regained popularity in the late 20th century. As a colonial instrument, they aimed to both limit money creation while also avoiding the need to transport currency between the home country and the colony. In their more recent use, they were intended as either an instrument to help curb and stabilise inflation, or to support new currencies in gaining credibility and acceptance. The following table lists historic and current CBAs.

Country/Territory	Start Year/End Year	Notes
Mauritius	1849 mid–20th c.	First currency board (British colony)
Falkland Islands	1899–present	British Overseas Territory; still operates board
Gibraltar	1914–present	British Overseas Territory; still operates board
West African Colonies	1912–1964	Board applied to multiple colonies
East African Colonies	1919–1869	Board applied to multiple colonies
St. Helena	1904–present	British Overseas Territory; still operates board
Ceylon/Sri Lanka	1884–1950	Linked to Indian rupee, then own currency
Hong Kong	1935–present	Peg to US dollar since 1983
Argentina	1991–2002	Peg to US dollar, not strictly orthodox
Estonia	1992–2011	Peg to DEM, then EUR; ended with euro adoption
Lithuania	1994–2015	Peg to DEM, then EUR; ended with euro adoption
Latvia	1994–2014	Peg to SDR, operated like a currency board but not legally anchored
Bulgaria	1997–2025	Adoption of euro on 1 January 2026
Bosnia and Hercegovina	1997/1998–present	Peg to DEM, now EUR; mandated under the Dayton agreement
Djibouti	1949–present	Peg to US dollar, ongoing
Cayman Islands	1972–present	Peg to US dollar, ongoing
Bermuda	1972–present	Peg to US dollar, ongoing
Macao	1983–present	Peg to Hong Kong dollar (indirectly to US dollar), ongoing

Source: Wolf et al. (2008) and authors' updates

Appendix 2: EU Membership and Monitoring of Legal and Institutional Progress in Bulgaria

In previous membership cases, convergence towards EU standards had to be achieved at the time of membership. Given the deeper-seated problems and expectations of a possibly longer reform process, the EU took the view for Bulgaria and Romania that some of the key changes, if closely monitored, could take place in the context of membership.

To achieve the necessary changes, the EU instituted a bespoke Cooperation and Verification Mechanism (CVM) for Bulgaria and Romania as a special post-accession monitoring tool to track progress on judicial reform, fighting corruption and (specifically for Bulgaria) tackling organised crime. It involved regular reporting, country benchmarks and an annual European Commission assessment. The process was formally closed in September 2023 after fulfilling its benchmarks.

CVM Contents

- The mechanism measured progress via six key benchmarks for Bulgaria, focused on judicial independence, combatting high-level corruption and improving the prosecution of organised crime.
- The CVM process produced regular (typically annual) public reports with detailed progress evaluations and recommendations.
- These reports incorporated consultations with Bulgarian authorities, civil society, and the EU Council and Parliament.

CVM Process

- Bulgaria was subject to scheduled reviews and Commission country visits, producing regular public reports available online.
- The Commission determined closure only after all benchmarks were satisfied, with a formal notification to the EU Council and Parliament for their observations before repeal.
- Since September 2023, Bulgaria now follows the standard EU Rule of Law cycle, with annual reporting and recommendations applying to all member states.[18]

Appendix 3: Legal and procedural process of entering into the EU's Exchange Rate Mechanism (ERM) II

ERM II is a framework established by the European Union to manage the exchange rates between the euro and the currencies of EU countries not yet using the euro, aiming to achieve convergence and exchange rate stability as part of the preparations for euro adoption. A period of at least two years in ERM II is a precondition for euro adoption. The ECB and European Commission monitor compliance, and publish "Convergence Reports" at least every two years to assess readiness to advance to euro membership.

[18] Source: https://www.pubaffairsbruxelles.eu/eu-institution-news/college-meeting-cooperation-and-verification-mechanism-cvm-reports-for-bulgaria-and-romania/ (downloaded: 19 September 2025) and Wahl (2023)

Specific conditions and the process are as follows:

- *EU membership* is a formal precondition for joining ERM II, but no timeframe for joining is specified. If a member state desires to join ERM II, the country's finance minister and central bank governor apply jointly to both the Eurogroup and the ECB.
- *Central exchange rate agreement*: ERM II allows the currency of a non-euro EU member to fluctuate against the euro within agreed limits, typically ±15 per cent around a central rate coordinated by the ECB and the national central bank. Currency board countries linked to the euro can maintain their arrangement (in practical terms a 0-per cent band).
- *Convergence commitment* ("*Maastricht Criteria*"): To move from ERM II to euro adoption, a country must meet the Maastricht criteria:
  - *Price stability*: Inflation rate no more than 1.5 percentage points above the average of the three best-performing EU member states.
  - *Sound public finances*: Government deficit must not exceed 3 per cent of GDP, and government debt should not exceed 60 per cent of GDP or be sufficiently diminishing towards that level.
  - *Exchange rate stability*: Participation in the Exchange Rate Mechanism II (ERM II) for at least two consecutive years without severe tensions or devaluation against the euro.
  - *Long-term interest rates*: Nominal long-term interest rates not more than 2 percentage points above those of the three best-performing member states in terms of price stability.
- *Approval by euro area partners*: Once the ECB and Eurogroup issue supporting Convergence Reports, existing euro and finance ministers and ECB must agree to the country's entry.[19]

[19] Source: *European Commission* (*2018*)

Natural Language Processing-Driven Use-Cases for Economic Analysis Using Unstructured Data*

Csanád Temesvári – Beáta Horváth – Lívia Réka Ónozó

Economic text data, such as news articles or retail trade item names, are an alternative, feature-rich, high frequency information source that can provide insight into economic trends and generate timelier and more accurate estimates. We trained multiple deep learning models for two distinct research tasks: 1) the creation of a sentiment index derived from the categorisation of financial and economic articles into three sentiment categories; and 2) the classification of retail trade item names into appropriate tariff categories. Our models consistently outperformed their baseline counterparts for retail trade item classification, while our sentiment index was able to accurately predict economic downturns where high-frequency data were not available.

Journal of Economic Literature (JEL) codes: C43, C45, C60

Keywords: Natural Language Processing, Deep Learning, macroeconomic nowcasting, classification

1. Introduction

The rapid growth of Natural Language Processing (NLP) and the availability of large-scale textual data provide a powerful tool for economists to analyse information. Within economics, the text-as-data paradigm has become one of the most dynamic methodological frontiers, allowing researchers to extract sentiment and narratives directly from unstructured sources such as news, corporate filings, and online media. Recent comprehensive reviews, such as *Ash – Hansen* (*2023*) and *Gentzkow et al.* (*2019*) have documented this transformation, emphasising the centrality of text-based measures in modern empirical economics. More broadly, the intersection between machine learning, NLP, and economic forecasting is now recognised as a key research domain, connecting to foundational work on nowcasting and real-time macroeconomic monitoring (*Babii et al. 2021*).

* 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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Parallel progress in NLP itself has been driven by deep neural networks and, most notably, transformer architectures (*Vaswani et al. 2017*). Models such as Bidirectional Encoder Representations from Transformers (BERT, *Devlin et al. 2019*) have set new performance benchmarks across diverse text classification and sentiment analysis tasks, and they are still a competitive class of models in the Large Language Model era (*Rostam – Kertész 2025*). These architectures enable contextual understanding that differs from traditional dictionary-based or bag-of-words methods, which struggle with words having multiple meanings and negation. In economics, this has encouraged a different avenue from handcrafted lexicons (*Tetlock 2007, Loughran – McDonald 2011*) toward contextual embeddings, resulting in richer, more accurate representations of economic narratives (*Nasiopoulos et al. 2025*). The main application of transformer-based models is in transfer learning, where a model is first trained on billions or even trillions of words or subwords known as "tokens" in a semi-supervised setting, with the goal of predicting the next token from an input of several tokens. This encourages the model to learn the pattern of the human language to build a foundational knowledge. Next, the model is trained on a task-specific corpora such as economic or financial texts, to achieve superior predictive performance in a domain-specific context, known as "finetuning". This enables the final model to exploit both the knowledge of human language, and to be able to perform in a domain such as finance (*FinBERT, Huang et al. 2022*) or scientific texts (*SciBERT, Beltagy et al. 2019*).

Sentiment analysis of economic news gives insights into public mood and market trends, without delays (*Ónozó et al. 2024b:1*). The ability to generate high-frequency indicators from textual sources provides policymakers and economists with near-real-time signals that complement lagging official statistics. At the EU level as a whole, *de Bondt – Sun* (*2025*) created a classification system using ChatGPT to assign hawkish or dovish sentiment to monthly global PMI reports. The authors successfully used these scores in a regression setting to improve the accuracy of the euro area GDP nowcast estimates. At the country level, *Kalamara et al.* (*2022*) created a sentiment index from articles from three prominent UK newspapers with both occurrence-count and supervised machine learning methods. Their index, in combination with other metrics, had remarkable predictive power for "proxy" metrics, widely used by British economists and policymakers. Both *Aguilar et al.* (*2021*) and *Sobrino et al.* (*2020*) constructed a sentiment index for the Spanish economy via keyword searching, using seven major news sites and the quarterly reports of the Bank of Espana, respectively. Both indices were found to perform better at nowcasting national GDP and GDP growth than a survey-based proxy measurement.

With a limited pool of readily available economically relevant sentiment data, manual annotation is needed to create a sufficient dataset for finetuning.

However, this annotation requires significant manual labour and collaboration. To counteract this, active learning (AL) has emerged as a way to combine a small amount of manually annotated data with a large surplus of available, unlabelled examples. Active learning selectively identifies the most informative examples for labelling, thus considerably reducing the annotation burden, while maintaining (or increasing) model performance. There are multiple strategies to find the most informant datapoints, ones that choose examples which are semantically similar to previously misclassified sentences (*Jiang et al. 2012*) or ones where our model is not as "confident" in its prediction (*Schröder et al. 2022*) or both (*Chen et al. 2011*). While the annotators are still mostly human annotators, there is an increase in using LLMs both as annotators and as methods to choose from the unlabelled data, such as pruning not promising datapoints or ranking the data for selection. LLMs are also being used as a vehicle for creating new labelled instances (*Xia et al. 2025*). These heuristics have been used effectively for multiple different NLP tasks, demonstrating their power in creating efficient data generation for training machine learning models (*Settles 2011; Zhang et al. 2022*). A notable example for using active learning in NLP for Hungarian data is *Üveges et al.* (*2024*), wherein the authors classify legal documents into law categories using deep learning models. The use of active learning managed to narrow down the data needed to reach baseline accuracy by up to 60 per cent.

This paper contributes to the literature by showcasing two instances of using transformer models for classifying Hungarian natural text data. First, we finetune different BERT models to generate sentiment scores for news articles. The data comes from two prominent Hungarian online news outlets. A topic modelling was chosen to create economically and financially relevant news database. We also used different AL heuristics to assess their efficacy in increasing model accuracy. The annotations were carried out using ChatGPT. The sentiment scores are then aggregated into a high-frequency sentiment index. This index is then evaluated for its predictive capacity and timeliness relative to key macroeconomic indicators, including gross domestic product (GDP), the purchasing manager's index (PMI), and the unemployment rate. For evaluating the predictive performance, we use the Granger causality test (*Granger 1969*) and in certain cases, the Toda-Yamamoto causality test (*Toda – Yamamoto 1995*), which are hypothesis tests to measure whether lagged values of one time series have a statistically significant power to predict a second series. We use dynamic time warping (DTW, *Berndt – Clifford 1994*) to measure the alignment between the sentiment indices and macro variables. Moreover, as text-based proxy indicators and indices are an effective way to predict crisis periods (*Baker et al. 2016*), we used a threshold autoregressive distributes lag (TADL, *Tong 1978*) model to assess whether or not the sentiment indices behave differently during crisis periods (such as the great financial crisis or the Covid-19 pandemic). As an additional point of interest, we performed inference with the

trained BERT models on a subset of the FineWeb dataset, a web crawl dataset from the CommonCrawl Repository.

Our second use-case trained transformer models to classify retail store receipt item names into Combined Nomenclature (CN) categories. The data was acquired from the National Tax and Customs Administrations and consists of receipts from major retailers in the country. We finetuned different BERT models to categorise the item names, where we created two different types of embeddings: one based on word co-occurrences, and one where the pretrained model's tokeniser created the vector representation.

The remainder of this paper is organised as follows. *Sections 2* and *3* showcase the two use-cases we investigated, both including the datasets we used, our methodology for the research, and our results. The conclusion follows in *Section 4*.

2. Sentiment analysis of news articles

2.1. Data

The first text data source was a collection of economic and financial news articles from two prominent Hungarian news portals that we scraped with the consent of the media. In accordance with the agreement between the central bank of Hungary and the news outlets, the publishers' name may not be disclosed: therefore, we refer to them as Medium 1 and Medium 2. The dates of the articles range from 1999 to 2020. To filter out economically and financially relevant articles, we used topic modelling, namely latent Dirichlet allocation (LDA). This method is trained on the whole corpus of Hungarian economic news articles to group similar news together. The model assumes that the articles arise from a mixture of latent "topics", and the number of topics is a hyperparameter. The training of the model starts out with a probability distribution for each article over the topics and each topic over the set of words and continually updates these using the word co-occurrences between different news in the corpus. By the end, each article will have a certain probability to fall into each topic. We used a grid-search approach to tune the hyperparameters, including the number of topics, and the number of articles the model processed in each iteration. The final model was chosen based on its perplexity, which measures the model's ability to generalise to new data. The final model used 16 categories and after a manual inspection of the top 20 most probable words for each topic, 13 of these categories were economically and financially relevant. The final dataset was constructed by filtering out the articles whose most probable topic was not in the selected relevant topics.

Figure 1 depicts the distribution of the number of articles broken down by year of publishing, while *Table 1* breaks down the numbers by medium. Our goal was two-fold: First, to train a machine learning model to assign a sentiment to a given

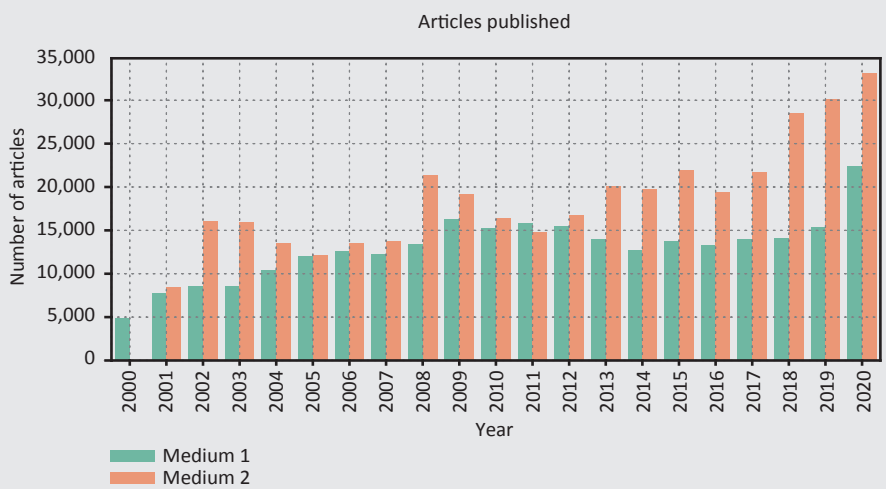
economic or financial article, whether it is positive, neutral or negative. Second, to aggregate these scores into a monthly sentiment index to assess its power to predict the drifts of the economy. To create a small, but usable labelled dataset, out of the 9 million sentences contained in the 700,000 articles we manually annotated 1,645 through a consensus approach, where three economic experts from the Magyar Nemzeti Bank (MNB, the central bank of Hungary) assigned a sentiment to each sentence, and the sentences' label was accepted if two out of the three votes matched. Out of these, a majority vote only occurred for 87 per cent of them, narrowing the dataset down to 1,431. For the training-validation-test data, we split the remaining articles according to a 70–20–10 per cent split, giving us 1,000 articles as training data, 287 as validation data for hyperparameter tuning and 144 for testing.

Table 1
Parameters of the text corpora

	Article count	Average monthly article count	First article	Last article
Medium 1	293,665	1,112	15-02-2000	31-12-2020
Medium 2	404,894	1,533	01-01-2000	31-12-2020
Total	698,545	2,645	01-01-2000	31-12-2020

Source: Arthur et al. (2023:3)

Figure 1
Annual evolution of the number of articles



Source: Authors' calculations

2.2. Methodology

For a baseline, we established a dictionary-based method. This approach uses a set of pre-defined words, which convey either positive or negative economic sentiment. It has many benefits: it is conceptually simple, it is computationally inexpensive, and the results are easily interpretable. However, the construction of this dictionary is not straightforward. Words that have negative sentiment in a common sense might lose this in a financial context, which makes the use of a general lexicon ineffective (*Loughran – McDonald 2011*). This led us to construct our own financial and economic dictionary. We aimed to not use a fixed corpus, as it would have made the dictionary restricted and would be biased to our specific dataset. The inference of this model consists of counting the number of words that are present in the dictionary, then summing their scores (+1 for a positive sentiment, –1 for a negative), then normalising it by the size of the whole dictionary. This results in a net sentiment score for an article, which conveys the overall sentiment: positive, if this number is greater than zero, negative if less than zero, and neutral otherwise. The index is created by averaging out the scores of all the articles in each month.

Our deep learning solution to classifying the news articles is based on two transformer models, both based on huBERT, a BERT model pretrained on the largest Hungarian web corpus (*Nemeskey 2020*). One of the transformer models is finetuned for named entity recognition (NER) (*Yang – Váradi 2023*), while the other is finetuned for sentiment analysis (*Yang – Laki 2021*). Both models are open-source models and are freely available on the Huggingface[1] platform (*NYTK/named-entity-recognition-nerkor-hubert-hungarian, NYTK/sentiment-hts5-hubert-hungarian*). Our model training included a thorough search for the optimal hyperparameters. We used the freely available Optuna[2] software library to streamline the computation, and all the different combinations were evaluated using the loss on the validation set to avoid overfitting, including the batch size, the number of epochs to train the model for, the dropout rate and the weight decay rate. Our experiment revealed that the batch size, the number of sentences that are given to the model at a time, was the most influential parameter, and therefore the most important to tune. This creates a trade-off between better resource management (small amounts of data create less strain on the system) and better generalisation (small amounts of data give less informant gradient for minimising the loss function). We did not modify any other hyperparameters and used the same configuration for both the NER and sentiment scoring models.

[1] https://www.huggingface.co
[2] https://www.optuna.org/

With our limited amount of annotated data, and a large corpus of unlabelled available news articles, using active learning to improve model performance was a suitable approach. Active learning is a human-in-the-loop methodology to increase the generalisation capabilities of a machine learning model. This entails an iterative fashion of training: after the model is trained on the initial training dataset, we select a subset of the unlabelled data which we think are the most useful for the model based on some heuristic, add these to the training data, re-train the model, etc. This process of iteratively labelling new data aims to use the least amount of data needed to train a performant classifier. Our experiments used three different heuristics. As a baseline, we sampled random sentences from our pool of unlabelled sentences, keeping in mind the distribution of the articles per month.

Our first heuristic uses the embedding vectors produced by our transformer models. We compute the embedding vectors for all the unlabelled sentences. Then we filter out the sentences from the test set, where the model predicted negative for a positive sentence, and vice versa. These data points provide the biggest learning opportunity for the model to correctly classify a sentence's sentiment. Next, we searched for all the unlabelled sentences whose *cosine distance* from any of the misclassified sentences is less than 0.00033 but still positive; this threshold was chosen based on the distribution of the different distances. Our final dataset is a sample from these new sentences. This form of active learning aims to provide better context for the model by labelling sentences which are semantically close to ones the model misclassified.

The second heuristic uses the prediction of the neural network to assess its uncertainty about its generalisation. Since we equipped the transformer models such that it is appropriate for classification, the output is a probability distribution over the available sentiment categories, negative, neutral and positive. We used the *entropy* corresponding to the prediction, calculated via *Equation (1):*

$$H(x) = -\sum_{i=1}^{3} p(x_i) \cdot log_2 p(x_i), \quad (1)$$

where $p(x_i)$ denotes the probability for each of the three possible outcomes. The closer to each other these probabilities are, the more uncertain the model is about its predictions. One outcome with a much higher probability conveys confidence about the model's decision. This approach hypothesises that the data which the model is uncertain about lies on the decision boundary of two categories, and therefore labelling those datapoints helps the model to achieve better accuracy. Our investigation revealed that around the entropy of 1.2 the maximum probability value had a noticeable increase. We used this threshold to sample sentences whose entropy exceeds that value. As a final heuristic, we implemented a sampling method which combined both the embeddings of the sentences as the output of the model

through the method called *uncertainty sampling*. We ranked all the unlabelled sentences according to the metric *m*, which was computed via *Equations (2)–(5)*:

$$s_{LC}(x) = 1 - \max_i p(x_i) =: 1 - p(x_{\max}) \tag{2}$$

$$s_{MG}(x) = |p(x_{max}) - p(x_{max-1})| \tag{3}$$

$$D_{avg}(x) = d_{cos}(x, \overline{x_{sen}}) \tag{4}$$

$$m(x) = \left(1 - D_{avg}(x)\right) \cdot \left(0.6 \cdot s_{LC}(x) + 0.4 \cdot s_{MG}(x)\right) \tag{5}$$

where $s_{LC}(x)$ denotes the *least confidence,* which measures how confident the model is in its most probable prediction, $s_{MG}(x)$ measures the *margin* between the first and second most probable answer, while $D_{avg}(x)$ is the cosine distance of the embedding of the sentence from the average embedding $\overline{x_{sen}}$.

For each heuristic, the samples consisted of 5,000 unlabelled sentences; this was deemed to be an appropriate amount of additional training data for the models. The labelling was done by ChatGPT using the official OpenAI API. As economic news articles contain a large proportion of neutral sentences, we reduced all categories of the newly labelled data to the sentiment with the lowest number of sentences, in order to create a balanced dataset for all active learning strategies. The new labelled sentences were added to the original training data, and the model was retrained with the extended dataset. This iteration of picking out new unlabelled sentences and annotating them using ChatGPT was carried out four times in total to produce the final models.

The time series aggregation methodology followed a hierarchical structure from sentence-level to monthly level indices. First, we extracted the sentence-level sentiment. The article-level sentiment index was constructed by summing the sentiment scores of all sentences within each article, providing a comprehensive measure of the overall sentiment tone of the text. The monthly level sentiment indices were computed by taking the arithmetic mean of all article-level sentiment scores within each month, enabling comparison with monthly macroeconomic data.

We compared the monthly sentiment index aggregated from the sentiment scores to three different macroeconomic time series. *Gross domestic product* (GDP)[3] measures the total value of all final goods and services produced within a country's borders over a given time period. It serves as a key indicator of a nation's economic activity and overall economic health. The *unemployment rate*[4] is a survey-based indicator that represents the percentage of the economically active population

[3] Data source: MNB
[4] Data source: Eurostat

who are without work, according to the International Labour Organization (ILO) definition. The *purchasing managers' index* (PMI)[5] is an economic indicator comprised of monthly reports and surveys from private sector manufacturing firms. It reflects business conditions such as production, new orders, employment, and supplier deliveries, with values above 50 indicating expansion and below 50 indicating contraction.

Identification of the macroeconomic variables was done through a systematic empirical approach using rolling window correlation analysis. Specifically, we employed a rolling window to identify the economic indicator that demonstrated meaningful co-movement with our sentiment indices. This data-driven process made it possible that only those macroeconomic variables were included in the final analysis that exhibited similarities with our sentiment measures. This approach allowed us to capture time-varying relationships and identify patterns across different time periods, which aimed to make robust variable selection. For both GDP and the unemployment rate, year-over-year measures are used, as these indicators are more suited to capturing the long-lasting effects conveyed through news dynamics. Due to the data generation process, there may be discrepancies in the temporal alignment, which could affect the interpretation of the results. The monthly GDP estimate is an internal indicator created by the MNB. The unemployment data come from the Hungarian Central Statistical Office (HCSO). For the direct estimation of the monthly unemployment rate, the HCSO uses state space models to estimate monthly employment and unemployment data (*Horváth – Lovics 2023*). The PMI data is published by the Hungarian Association of Logistics, Purchasing and Inventory Management (HALPIM).

2.3. Evaluation

To assess the efficacy of our training, we used several metrics that are well known for their use in machine learning. For classification, we used the weighted precision, recall and F1 score and the balanced accuracy score. These metrics combine the measures for all classes, computing a weighted average of the metrics for each category with the number of elements as the weight, to give an over-encompassing and balanced metric for the capabilities of the model.

For the generated sentiment index, we used two different time series alignment measures. The first one is the Granger causality test (*Granger 1969*), which is a statistical hypothesis test to assess whether or not a series can predict another one, or rather, whether past values of one series contain information that helps to forecast the other. For two time series *X* and *Y*, two autoregressive models are constructed via *Equation (6)* and *(7)*:

[5] Data source: Investing.com [Hungary Manufacturing Purchasing Managers Index (PMI)]

$$Y_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i Y_{t-i} + \varepsilon_t \quad (6)$$

and

$$Y_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i Y_{t-i} + \sum_{i=1}^{p} \beta_i X_{t-i} + \varepsilon_t \quad (7)$$

The null hypothesis states that *X* does not Granger-cause *Y*, which is equivalent of the following:

$$H_0: \beta_1 = \beta_2 = \cdots = \beta_q = 0 \quad (8)$$

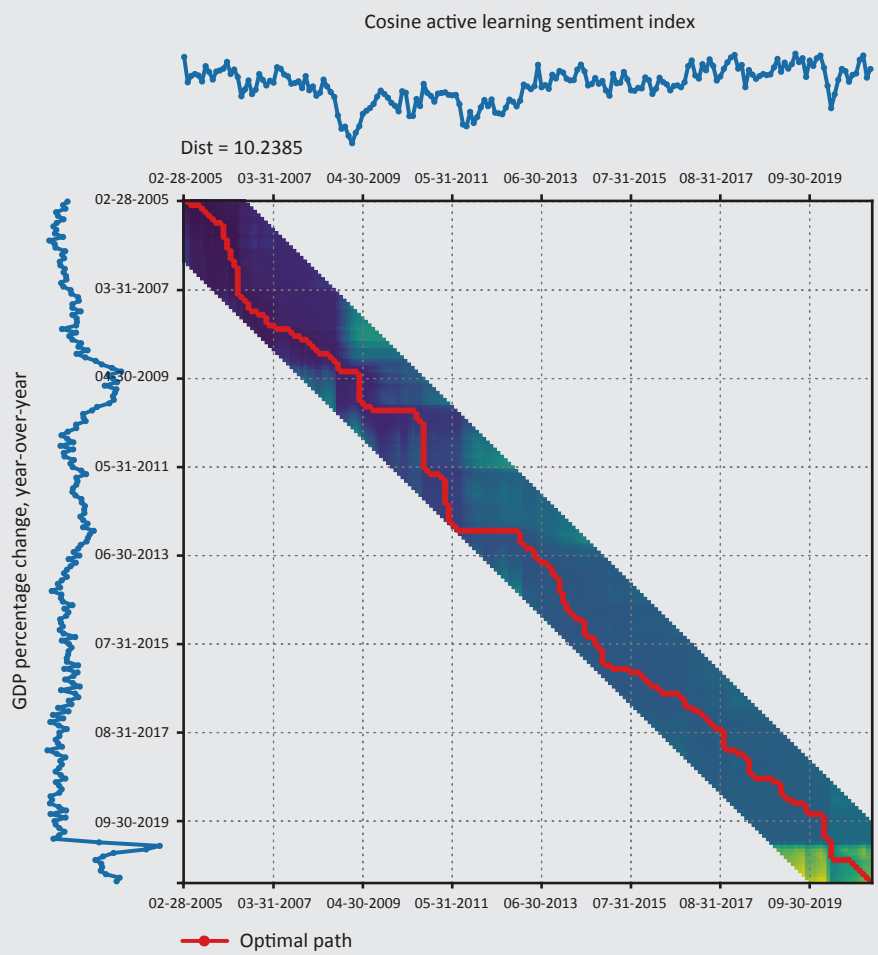
Equation (8) states that the coefficients β_j are all zero, meaning no past values of *X* are significant in predicting *Y*. If we can reject the null hypothesis at a certain level, it means that lagged values of *X* have statistically significant predicting power for future values of *Y*. The Granger causality test assumes that the time series are stationary. This will be tested using the augmented Dickey–Fuller statistical test (ADF, *Dickey – Fuller 1979*). If the results of the ADF test indicate that a time series is non-stationary, the Toda–Yamamoto (*Toda – Yamamoto 1995*) procedure was applied to test for Ganger causality. The method involves determining the maximum order of integration (d_{max}) among the variables and selecting the optimal lag length (*k*) for the standard VAR model. Subsequently, a *VAR(k+*d_{max}*)* model is estimated and the causality test is conducted using Wald tests on the first coefficient matrices, ignoring the last d_{max}. This augmentation enables robust Granger causality testing even when the variables are non-stationary or cointegrated. The order of the autoregressive expressions *p* is a parameter that we need to set ourselves. To find the optimal lag order value, we reported the Bayesian information criterion (BIC, *Schwarz 1978*) and the Hannan–Quinn information criterion (HQ, *Hannan – Quinn 1979*) for all values of *p* up to 8, then chose the one with the smallest BIC and HQ score, and ran the Granger causality test with that parameter.

The second method to evaluate the alignment of two time series is dynamic time warping (DTW, *Proakis – Manolakis 2007*), which tries to find the optimal alignment between two series of numbers. For each point in the first series, the algorithm tries to find the point in the second series with the lowest Euclidean distance to it. The algorithm outputs a pairing, which must satisfy three conditions: 1) each point in one sequence must be paired up with a point in the other; 2) the first and the last points must be paired with each other; and 3) the pairs must be monotonically increasing, meaning the pairs cannot "cross" each other. In practice, another restriction called *global constraint* is also applied, i.e. the admissible points are those whose positions in the two series are "close" to each other. Take, for example a window size greater than 0, then for the coordinate *j* in the first series, the paired up index *i* must be in the interval [*j–w, j+w*]. This not only alleviates a heavy computational burden from trying to compute the distance of every different combination of pairs of points which would result in a quadratic time complexity but

is also in line with a locality argument, namely we are interested in local similarities between our proxy indicators and the macroeconomic variables.

The algorithm produces a pairing of the two time series that pairs the endpoints to each other and is monotonically increasing in both series. *Figure 2* depicts an example of an optimal path between two sequences. The y-axis corresponding to the macroeconomic variable and the x-axis to the sentiment index generated from a model's predictions. The coloured fields are the eligible pairings according to the global constraint, while their colour scale represents the cost of a pairing, measured in the Euclidean distance between the two data points in the series, with darker colour denoting a lower value. The red dots denote the coordinates of the optimal pairings, and the *Dist* field is the sum of all costs of the pairs.

Figure 2
Optimal DTW cost path of the cosine active learning index and the year-over-year GDP index



Source: Authors' calculations

Threshold autoregressive distributed lag (TADL) models were estimated to investigate whether the overall fit between the news indices and macroeconomic data differs during crisis and non-crisis periods. TADL models are particularly useful in capturing regime shifts and nonlinear dynamics in time series data, as they help reveal whether underlying economic relationships change significantly under different conditions. The number of regimes and the threshold values were determined using the Bai–Perron test (see *Bai – Perron 1998*).

The TADL model extends the standard threshold autoregression (TAR) model specification by allowing contemporaneous and distributed lag terms. In the case of a two-regime TADL model, the formulation is shown in *Equation (9)*:

$$y_t = \begin{cases} c_1 + \sum_{i=1}^{p} \alpha_{1,i} y_{t-i} + \sum_{j=0}^{q} \beta_{1,j} x_{t-j} + \varepsilon_t, & \text{if } y_{t-1} \leq \gamma \\ c_2 + \sum_{i=1}^{p} \alpha_{2,i} y_{t-i} + \sum_{j=0}^{q} \beta_{2,j} x_{t-j} + \varepsilon_t, & \text{if } y_{t-1} > \gamma \end{cases}; \quad (9)$$

where y_t is the dependent variable at time t; x_{t-j} are the lagged values of the explanatory variable; y_{t-i} are the lagged values of the dependent variable; $\alpha_{1,i}$ and $\alpha_{2,i}$ are the autoregressive coefficients for the dependent variable in regime 1 and 2, respectively; $\beta_{1,i}$ and $\beta_{2,i}$ are the coefficients for the explanatory variable in each regime; γ is the threshold value that determines the boundary between the two regimes; and ε_t is the error term.

2.4. Results

Table 2 summarises our results for the model training. We chose the sentiment model trained with no active learning as the baseline, as the active learning models were building upon this model, making it a natural candidate. This also allowed us to evaluate how much performance the different active learning heuristics provide. The overall best performing model was the model with the cosine-based active learning, achieving the highest accuracy. The uncertainty-based active learning model had the best performance in categorising neutral sentences, which we deemed important, as the news articles' sentiment is heavily imbalanced towards neutral sentiment. We chose these two models to generate the sentiment indices from the database of news. The optimal DTW distances are introduced in *Table 7* in the *Appendix*. For the PMI, both active learning models generated a comparable result. The dictionary-based method achieved the lowest distance to year-over-year GDP change, while for the unemployment rate, the BERT models achieved a lower distance than the dictionary-based model.

Table 2
Results of sentiment classification finetuning

Model	Precision (%)	Recall (%)	F1-score (%)	Balanced Accuracy (%)
Baseline sentiment model	62.64	63.19	62.47	62.16
Uncertainty active learning (AL) model	65.76	65.28	65.35	65.14
Cosine active learning (AL) model	70.77	70.14	70.29	70.19

Source: Authors' calculations

The optimal lag length analysis yielded the same results for PMI and GDP, using both the BIC and HQ criteria. For the unemployment rate, we considered the HQ results, taking into account the properties of the unemployment rate series. The results can be found in *Table 6* in the *Appendix*.

The Granger causality analysis indicates that all news sentiment indices contain information that helps to forecast the examined macroeconomic indicators. In the case of the unemployment rate, cosine AL sentiment index and uncertainty AL sentiment index, the Toda-Yamamoto methodology was applied. The results of the stationarity tests are presented in *Table 5* in the *Appendix*, while the Granger causality tests are reported in *Table 3*.

Table 3
Granger causality test results: OLL based on HQ and Granger test type as indicated in Table 5

	Cosine AL sentiment index	Uncertainty AL sentiment index	Dictionary-based sentiment index
GDP YOY	0.0678	0.063	0.0000
PMI	0.0004	0.0002	0.0000
Unemployment rate YOY	0.0255	0.017	0.0000

Note: YOY: Year-over-Year
Source: Authors' calculations

The TADL analysis of macroeconomic variables and sentiment indices supports the findings that the overall fit between the news indices and macroeconomic data differs between crisis and non-crisis periods. In the following analysis, the economic indicators are used as dependent variables and the cosine AL sentiment index is used as the independent variable, representing the best-performing model, as shown above. In the case of the PMI, two regimes were identified. The threshold value is 49.5, which aligns the PMI index's formulation, where a value below 50 indicates contraction. When the values are below the threshold, both lagged and coincident sentiment indices are statistically significant, indicating a leading and predictive effect. By contrast, in the other regime, the relationship suggests contemporaneous co-movement. For GDP, the TADL model identifies three distinct regimes: one

that corresponds to periods of substantial decreases, another that corresponds to periods of "normal" changes, and a third that corresponds to periods of substantial increases. The results show that the lagged variables of the news sentiment indices have different effects across these regimes. In the regime with decreasing GDP, the effects are leading meaning the lagged variables have predictive effect, while in the period of "normal" changes, the impact is not statistically significant. By contrast, during the increasing period, the news index suggests a simultaneous association with GDP. For the unemployment rate, the TADL model identifies four distinct regimes: one for large decreases in unemployment rate changes, two for moderate changes, and one for surge increases in unemployment rate changes. The results suggest that very different processes are taking place in the four regimes. Only during periods of surge increases in the unemployment rate changes do the lagged variables of the news index become significant, indicating a leading and predictive effect. The outcomes of the TADL analysis can be found in *Table 8* in the *Appendix*.

2.5. Inference on the Fineweb2 dataset

As a further evaluation of our active learning-aided transformer models, we sought to generate another index from a different Hungarian dataset. The Fineweb2 dataset is a multi-trillion token natural text dataset from more than 1,000 languages, consolidated from the CommonCrawl open repository of web crawl, to create a clean, multilingual dataset for all NLP tasks. Each datum is a snapshot of the textual information from a website, preprocessed through a special pipeline, which includes deduplication of the website content, filtering for NSFW sites, and fixing encoding issues. For a detailed explanation on the preprocessing, see *Penedo et al.* (*2025*).

We selected the Hungarian portion of this dataset, which consisted of text from 50 million websites, with timestamps ranging from March 2013 to April 2024. We used the LDA model trained on the news articles to infer the latent topics and kept the data which fell into the same pre-defined categories. As processing the whole filtered dataset was not feasible on a reasonable timescale, we decide to take a randomised sample, where we chose 100 datapoints from each day. This resulted in 110,000 unique websites, comprised of 3,665,315 sentences which we deemed enough data to create the index. The inference of the models and the index generation were conducted in the same manner as described in *Section 2.2*. *Figure 4* in the *Appendix* shows the chart of the generated indices for the cosine AL model, compared against the year-over-year GDP percentage change. The sentiment index went through a linear scaling, and thus its minimal and maximal value equals the corresponding minimal and maximal value of the GDP change. The sentiment indices seem to follow the dynamics of GDP, especially at the onset of the Covid-19 pandemic. In response to Covid-19, both GDP and sentiment indices experienced a significant decline. However, the drop in the sentiment indices appears to be more persistent. One possible reason for this is that the news, focused for an extended period on the economic burdens caused by Covid and the long-term effects of the

resulting uncertainties. The continuous flow of negative information, combined with the slow recovery of the economy, may have contributed to the indices remaining at a low level for a prolonged period. However, no clear lead-lag relationship could be found between the two series.

3. Retail trade items classification

3.1. Data

For the trade item classification task, we used an extract of the Online Cash Register, a list of approximately 445,000 unique trade item names provided by the Hungarian National Tax and Customs Administration (NAV). Our goal was to finetune a model to predict the item's Combined Nomenclature (CN) code, which is the European Union's standard for classifying retailed goods and is built on the Harmonised System (HS). The CN code is an eight-digit hierarchical code system, with each two additional codes refining each category. In our dataset, only 53,292 unique trade items had a valid four-digit CN code. Within these categories, we selected 17 of these four-digit categories as our focus, as these categories were retail item categories (as our research focus), and with enough items for a finetuning to be effective.

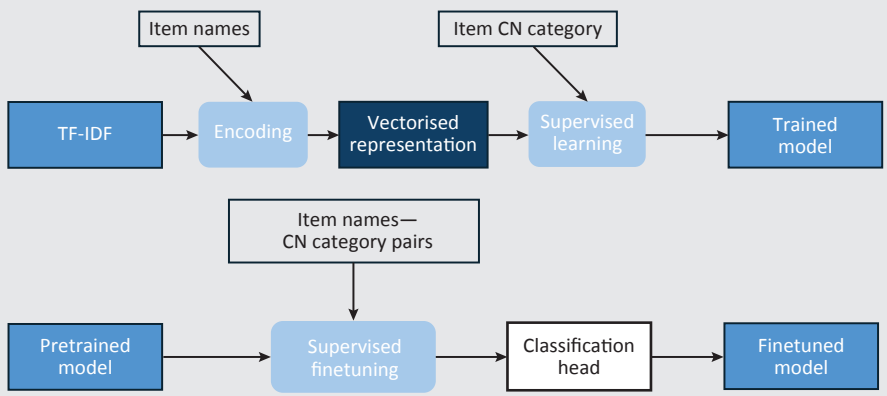
The data cleaning consisted of the following steps: first, cleaning any marker that could point to the retailer the receipt was from (e.g. the name of the store for a store-exclusive product). For privacy and security reasons, this step was carried out by the Tax Authority, which removed any empty items, instances that do not correspond to products (discounts, coupons) and any extra characters (commas, colons, white spaces). Many items had, as part of their name, an indication about the packaging (empties, weight, measurements). For the second step, we created two datasets: one in which this extra information about packaging is removed, and one where it is not, and compared the performance of the models on both datasets. We first split the dataset into an 80–20 per cent part for the train-test split, and then we took a 10-per cent random sample from the training data for the validation split.

3.2. Methodology

We identified two different possibilities to create embeddings. First, we created them through a modified TF-IDF (Term Frequency—Inverse Document Frequency) algorithm (*Sparck Jones 1972*), which uses character co-occurrences to create similar vectors for similar item names. The models trained using the first method are called *vectorised* models. The second option was to let the pretrained model create its own vector representation through its tokeniser. We compared three different models: RoBERTa (*Liu et al. 2019*), huBERT (*Nemeskey 2020*) and PULI (*Yang et al. 2023*). All models are transformer-based open-source models and are available on HuggingFace (*SZTAKI-HLT/huBERT-base-cc, sentence-transformers/all-roberta-large-v1, NYTK/PULI-GPT-2*). For the finetuned models – since language models are next-token predictors – we modified the final layer to align with our goals for

classification. This process led us to create and compare six different models. The final training pipeline of the methodologies is depicted in *Figure 3*.

Figure 3
Schematic of the vectorised learning and finetuning



Source: Authors' compilation

3.3. Results

The results are summarised in *Table 4*. For all models and training, the performance was better on the dataset in which the packaging information was not removed, compared to the one where it was, meaning that this information was helpful for the models to distinguish between different categories. While only looking at the precision values one could think the two different training paradigms were close in performance, a more comprehensive metric such as the balanced accuracy reveals the superiority of finetuning over using only the embeddings generated from the models. This difference indicates that the attention mechanism that drives transformers is capable of capturing semantic relationships between different parts of the items' description better than a simple co-occurrence algorithm. For both vectorised and finetuned models, the huBERT based model was the best performer in most metrics. This is an expected result, as the PULI model is a generative model, which is less suited for classification tasks. Their mutual dominance over the RoBERTa model can be attributed to the fact that, while RoBERTa was pretrained on a multilingual corpus, both huBERT and PULI were pretrained solely on a Hungarian language corpus, making them suitable for tasks with predominantly Hungarian data.

Table 4
Vectorised and finetuned model results

Model	Precision (%)	Recall (%)	F1-score (%)	Balanced Accuracy (%)
Vectorised RoBERTa	61.29	17.32	6.27	6.66
Vectorised huBERT	60.45	17.35	6.34	6.67
Vectorised PULI	61.96	17.22	6.06	6.58
Finetuned RoBERTa	85.84	85.73	85.69	83.42
Finetuned huBERT	88.02	87.97	87.93	85.82
Finetuned PULI	86.63	86.49	86.44	83.95

Source: Authors' calculations

4. Conclusions

Our study investigated Natural Language Processing methodologies, leveraging deep learning models, more precisely transformer-based architectures for creating high-frequency, low-latency indicators from unstructured economic texts. We used financial and economic news articles akin to *Kalamara et al.* (*2022*) and *Aguilar et al.* (*2021*) and retail trade item names and transformed them into actionable classification instruments. These feature-rich sources served as a good basis to generate accurate estimates of economic dynamics, which were validated by the techniques used.

For the sentiment analysis, our deep learning models were effective in assigning sentiment categories to different articles. The use of active learning heuristics enhanced model generalisation capabilities and rendered the models more effective by using less training data needed for finetuning, similar to *Üveges et al.* (*2024*). The cosine-based AL model achieved the highest overall accuracy, while the uncertainty-based AL model demonstrated remarkable performance in classifying neutral sentences, a critical capability given the heavy imbalance toward neutral sentiment in economic news data. The resulting sentiment index proved to be effective in predicting economic downturns, particularly where high-frequency data were unavailable.

The time series analysis revealed complex, regime-dependent predictive relationships between the news sentiment indices and key macroeconomic variables. The main methodologies used in our paper show the following results:

1. Granger causality and dynamic time warping (DTW): The Granger causality analysis indicated that all derived news sentiment indices contain statistically significant information for forecasting the examined macroeconomic indicators.

Regarding optimal alignment, the dictionary-based method yielded the lowest DTW distance when compared to year-over-year GDP change and the PMI, but the active learning-based indices achieved a better fit for unemployment change.

2. Threshold autoregressive distributed lag (TADL) Analysis: The TADL models, estimated to capture regime shifts, confirmed that the correlation between news indices and macroeconomic data differs significantly between crisis and non-crisis periods.

Our results show that in the domain of retail trade item classification, the implemented models – specifically, the finetuned transformer architectures (RoBERTa, huBERT, PULI) – exhibited superior performance relative to their baseline counterparts, and this gain was demonstrated by the balanced accuracy scores. The huBERT model pretrained on a Hungarian language corpus proved to be the optimal performer across most classification models, highlighting the benefit of language-specific pretraining for tasks involving Hungarian language analysis. Furthermore, the inclusion of packaging information within the trade item names enhanced model efficacy, indicating its utility in distinguishing between product categories. A performant classifier in the task of classifying retail items would be a welcome addition to the NLP ecosystem, as misclassifying such items has major legal and material consequences (*Ónozó et al. 2024a:133*).

In summary, this study demonstrates the significant potential of applying advanced deep learning and NLP techniques to unstructured data, offering a valuable toolkit for macroeconomists and decision-makers on the market seeking enhanced predictive power and a deeper understanding of nonlinear economic dynamics. Future research directions could include developing a more sophisticated sentiment category system to create specialised sentiment indices, which would enable more granular analysis of economic narratives and their different impact across economic domains.

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Appendix

Table 5
Results of the ADF and KPSS stationarity tests

	p-values of ADF	LM statistics for KPSS	Integration	Granger test
GDP YOY	0.0095	0.1483	I(0)	standard
Unemployment YOY	0.5325	0.4619	I(1)	Toda–Yamamoto
PMI	0.0000	0.1962	I(0)	standard
Cosine AL sentiment index	0.0042	0.6134	I(1)	Toda–Yamamoto
Uncertainty AL sentiment index	0.0044	0.8021	I(1)	Toda–Yamamoto
Dictionary-based sentiment index	0.0023	0.2500	I(0)	standard

Note: YOY: Year-over-Year
Source: Authors' calculations

Table 6
Optimal lag lengths for variable pairs based on Bayesian and Hannan-Quinn information criteria

Variable pairs	BIC	HQ	Included Observations
GDP YOY – Dictionary-based sentiment index	1	1	184
GDP YOY – Cosine AL sentiment index	1	1	184
GDP YOY – Uncertainty AL sentiment index	1	1	184
Unemployment YOY – Dictionary-based sentiment index	1	1	172
Unemployment YOY – Cosine AL sentiment index	1	1	172
Unemployment YOY – Uncertainty AL sentiment index	1	1	172
PMI – Dictionary-based sentiment index	1	3	184
PMI-Cosine AL sentiment index	1	3	184
PMI – Uncertainty AL sentiment index	1	4	184

Note: YOY: Year-over-Year
Source: Authors' calculations

Table 7
DTW values for all sentiment indices and macro-variables involved

	Cosine AL sentiment index	Uncertainty AL sentiment index	Dictionary-based sentiment index
GDP YOY	10.2385	10.6563	4.4337
Unemployment YOY	15.6824	16.0024	18.099
PMI	8.4366	8.8464	6.8814

Note: YOY: Year-over-Year
Source: Authors' calculations

Table 8
Results of TADL analysis on GDP, unemployment and PMI statistics using the Cosine AL index

Dependent Variable: GDP YOY Threshold variable: GDP YOY(–1)		
Variable	**Coeff**	**Std. Error**
GDP YOY(–1) < **–1.74** -- 28 obs		
C	–5.39***	0.36
COSINE AL	–195.65***	34.06
COSINE AL(–1)	223.39***	36.10
–1.74 <= GDP YOY(–1) < **2.44** -- 66 obs		
C	0.55**	0.25
COSINE AL	36.10*	20.72
COSINE AL(–1)	6.10	21.12
2.44 <= GDP YOY(–1) -- 97 obs		
C	1.75***	0.47726
COSINE AL	62.51***	17.04485
COSINE AL(–1)	10.22	18.2724

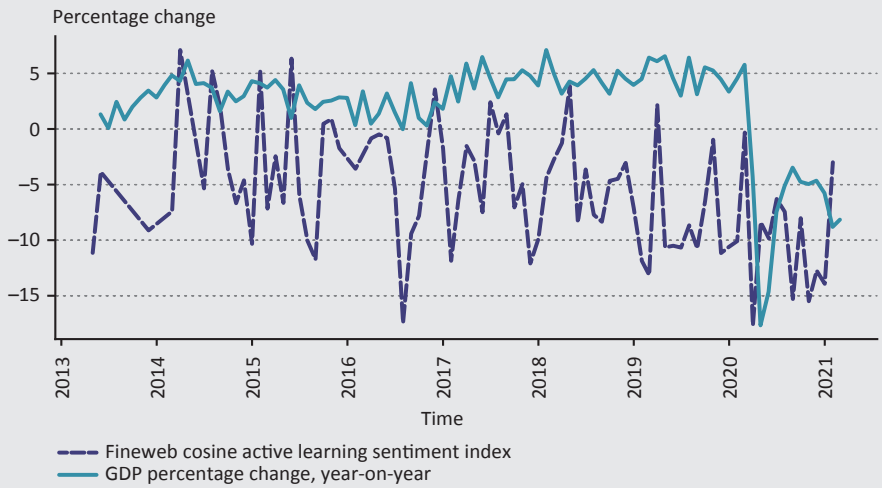
Dependent Variable: Unemployment Threshold variable: Unemployment(–1)		
Variable	**Coeff**	**Std. Error**
Unemployment(–1) < –10.53 -- 56 obs		
C	–26.13***	3.12
COSINE AL	146.06*	87.13
COSINE AL(–3)	131.54	89.80
–10.53 <= Unemployment(–1) < **–2.6** -- 37 obs		
C	–3.73**	1.80
COSINE AL	-138.57	95.55
COSINE AL(–3)	43.02	93.84
–2.6 <= Unemployment(–1) < **10** -- 58 obs		
C	1.81	1.11
COSINE AL	–113.62**	55.37
COSINE AL(–3)	100.81	62.56
10 <= Unemployment(–1) -- 28 obs		
C	21.77***	1.52
COSINE AL	356.83***	83.44
COSINE AL(–3)	–307.90***	78.75

Dependent Variable: PMI Threshold variable: PMI(–1)		
Variable	**Coeff**	**Std. Error**
PMI(–1) < **49.5** -- 29 obs		
C	46.87***	0.64
COSINE AL	–59.70	53.46
COSINE AL(–1)	167.05***	50.45
49.5 <= PMI(–1) -- 162 obs		
C	51.78***	0.42
COSINE AL	70.44***	25.04
COSINE AL(–1)	2.58	26.04

*Note: YOY: Year-over-Year, *** p < 0.01, ** p < 0.05, * p < 0.1*

Source: Authors' calculations

Figure 4
Sentiment index from the Fineweb dataset versus year-over-year GDP change



Source: Authors' calculations

Examination of the Sustainability Disclosure Practices at Banks Operating in Hungary*

Regina Bodó – Edit Lippai-Makra

The EU's directive on corporate sustainability reporting, which entered into force in 2022, brought changes to corporate disclosure practices. This study presents the potential effects of the new regulation on banks' disclosures. In the course of the research, the disclosure practices of obliged banks operating in Hungary were examined using content analysis. The results indicate that, as a consequence of the regulation, overall disclosure intensity decreased; however, this decline is driven more by formal than substantive changes. Reports place greater emphasis on descriptive content, while numerical and graphical disclosures have receded into the background. It can also be established that the sustainability reports of the examined banks have become more similar both in content and in form, confirming the unifying objective of the regulation.

Journal of Economic Literature (JEL) codes: G21, K32, M48, Q56

Keywords: bank, sustainability, CSRD, NFRD, content analysis

1. Introduction

Today's global challenges – including climate change, the energy crisis, natural disasters, and armed conflicts – may entail significant social and economic costs, potentially amounting to billions of dollars. At the same time, the concept of sustainable development is not new: the Brundtland Report ("Our Common Future") already called for environmentally sustainable growth in 1987, interpreting the satisfaction of present needs without compromising the opportunities of future generations. Accordingly, meeting current needs presupposes consideration of environmental constraints; neglecting these constraints may lead to an unsustainable development path in the long term (*Brundtland 1987; Papp et al. 2022*).

* 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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Sustainability considerations are increasingly integrated into corporate decision-making, including in the banking sector. This process is reinforced by EU policy initiatives: on 8 March 2018, the European Commission launched the Sustainable Finance Action Plan, emphasising the intermediary role of the financial sector in the green transition. Subsequently, on 11 December 2019, the European Union presented the European Green Deal, which aims to achieve climate neutrality by 2050 by supporting the green transition, reducing carbon emissions, promoting the use of renewable energy and encouraging the circular economy (*Kirschenmann 2022*). One of the pillars of the above regulatory framework is the regulation of sustainability disclosures. The first directive in this area, the Non-Financial Reporting Directive[1] (NFRD, 2014/95/EU), made the disclosure of sustainability-related information mandatory for certain large companies from 2017 onwards. In 2022, this framework was replaced by the Corporate Sustainability Reporting Directive[2] (CSRD, 2022/2464/EU), which not only expanded the scope of obliged entities, but also introduced stricter formal and substantive requirements for corporate sustainability reporting.

The focus of this research is the sustainability disclosure practices of banks operating in Hungary that fall under the personal scope of the CSRD. The study seeks to answer how the disclosure practices of the examined banks have changed as a consequence of the new regulation. In the empirical analysis, banks' sustainability disclosures were examined using content analysis for the year preceding and the year following the introduction of the CSRD. The study investigates how disclosure intensity has been impacted by the new regulation. The term 'disclosure intensity' is defined as the quantity of information disclosed, as well as a complex indicator that also takes into account the form of disclosure (text, data, graphs, etc.) (*Dumitru et al. 2017; Lippai-Makra 2025*).

2. Theoretical background

In this section, the extant literature and regulatory framework are taken as the basis upon which the corporate behaviour relating to the aforementioned topic, together with the relevant theories on reporting and the regulatory background, are presented.

2.1. Corporate behaviour

According to *Friedman's* (*1970*) classical position, the primary objective of corporate social responsibility is profit maximisation. This approach is still widely supported in the literature, although the role of non-financial considerations in corporate decision-making remains debated (*Hill 2020*). In early theoretical frameworks,

[1] https://eur-lex.europa.eu/eli/dir/2014/95/oj/eng
[2] http://data.europa.eu/eli/dir/2022/2464/oj

investment decisions were primarily determined by the optimisation of return and risk, in line with the assumptions of rational actors in neoclassical economic thinking (*Sherwood – Pollard 2018*). However, empirical findings have shown that neither aggregated market processes nor individual investment decisions can be fully explained by the assumption of perfect rationality. This led to the emergence of behavioural finance, which interprets investor decisions by considering bounded rationality, limitations in information-processing capacity and unconscious cognitive biases (*Barberis – Thaler 2003*). According to this perspective, investment decisions are influenced not only by financial indicators, but also by the interpretation of available information and the complexity of the decision environment. Among investors interested in non-financial information, a distinction can be made between those who primarily use such factors to assess corporate risk profiles and those who incorporate value-based considerations into their decisions (*Lippai-Makra – Kovács 2021*). At the same time, the literature does not provide clear evidence as to whether a value-based approach necessarily leads to superior financial performance, even though some authors emphasise the potential long-term competitive advantages associated with sustainability considerations (*Esty – Lubin 2020*).

The economic interpretation of sustainability is not new. *Soppe* (*2004*) addressed sustainable corporate finance early on in the context of environmental economics and business ethics, while corporate social responsibility disclosure was long considered primarily a Western phenomenon (*Barakat et al. 2015*). Following the Covid-19 crisis, increasing emphasis was placed on establishing more sustainable growth paths during economic recovery (*Esty – Cort 2020*). The transition to a low-carbon economy requires substantial investment in industry, transportation, energy and infrastructure sectors, in which the capital allocation mechanisms of the financial system play a crucial role (*Warshauer – Krosinsky 2020; Holczinger – Sárvári 2025; Papp et al. 2022*). Accordingly, a sustainable economic environment cannot be interpreted without a sustainable financial system (*Stamelos 2022*). Central banks increasingly recognise that climate change and the associated physical and transition risks may negatively affect price stability and financial stability, particularly if these risks are not adequately reflected in the pricing of financial assets (*Baranyai – Banai 2022; Kandrács et al. 2021; Papp et al. 2022*).

2.2. Reporting theories

Corporate reporting practices are generally summarised in the literature by four main theories: stakeholder theory, agency theory, signalling theory and legitimacy theory (*An et al. 2011; Omran – Ramdhony 2015; Ortas et al. 2015*). According to stakeholder theory, the firm is a coalition of stakeholder groups; therefore, reporting must satisfy the diverse information needs of these groups. Long-term survival depends on the alignment of stakeholder interests (*Lakatos 2013; Freeman 2010;*

Mahajan et al. 2023). The agency problem arises from the differing interests of owners and managers, which may reduce firm value through agency costs (*Jensen – Meckling 1976*). Signalling theory emphasises the reduction of information asymmetry: firms provide costly and therefore credible signals to demonstrate their quality to investors (*Connelly et al. 2011; An et al. 2011*). According to legitimacy theory, organisations strive for social acceptance by aligning with societal norms and communicating their compliance (e.g. through social and environmental reporting), particularly in environmentally sensitive industries (*An et al. 2011; Deegan 2014*).

In the past, companies were already required to disclose certain non-financial information, including information relating to sustainability. In this study, non-financial disclosure refers to disclosures beyond the four fundamental financial statements (statement of financial position, income statement, cash flow statement and statement of changes in equity). Sustainability disclosure refers to disclosures covering environmental, social and governance (ESG) issues. Based on the work of *Lippai-Makra et al.* (*2024*), the sustainability reporting process can be summarised as follows:

1. Identification of motivation – The company recognises the need for sustainability reporting, which may be driven by voluntary or mandatory regulations.

2. Development of reporting strategy – The company determines which topics and risks it intends to report on (e.g. environmental, social, governance factors).

3. Selection of methodology – The reporting format and applied sustainability standards are chosen (e.g. GRI,[3] SASB,[4] CDP,[5] TCFD[6]).

4. Preparation and publication of the report – The report is compiled and published for stakeholders.

5. Evaluation of feedback – Stakeholders assess the report, providing feedback that may improve future disclosure practices.

In this research, we focus on steps 2, 3 and 4 in the above process in relation to the sustainability disclosures of obliged banks operating in Hungary. Specifically, the study examines which topics are reported, how they are reported, according to which standards, and where the reports are accessible to stakeholders. Motivational factors and stakeholder feedback (steps 1 and 5) are not within the scope of this study.

[3] Global Reporting Initiative.
[4] Sustainability Accounting Standards Board.
[5] Carbon Disclosure Project.
[6] Task Force on Climate-related Financial Disclosures.

2.3. Regulatory background

2.3.1. Sustainable finance action plan

The EU Sustainable Finance Action Plan was launched in 2018 with the objective of supporting the transition to a carbon-neutral economy while strengthening sustainable growth and financial stability. It aims to create a more transparent and greener financial system. The Action Plan is built on three pillars.

The first pillar is the Taxonomy Regulation (EU 2020/852), which defines when an economic activity can be considered environmentally sustainable. It enhances transparency, reduces the risk of greenwashing, establishes technical screening criteria and social safeguards, and also has implications for the banking sector (*Kandrács et al. 2021; Kirschenmann 2022*). The second pillar is the mandatory disclosure framework. Corporate environmental and social impacts are regulated by the CSRD (EU 2022/2464), while business and financial risks arising from sustainability exposures are regulated by the Sustainable Finance Disclosure Regulation (SFDR, EU 2019/2088). The third pillar consists of investment tools (benchmarks, standards, labels), supported by the Regulation on EU Climate Benchmarks (EU 2019/2089), aligned with the objectives of the Paris Agreement. The focus of this research is the CSRD, adopted in 2022, which requires more detailed ESG disclosures, strengthens transparency and applies the principle of double materiality; the study examines its impact on the sustainability reports of Hungarian banks.

2.3.2. CSRD (Corporate Sustainability Reporting Directive)[7]

Before discussing the CSRD, it is imperative to refer to Directive 2014/95/EU[8] of the European Parliament and of the Council (NFRD), which introduced mandatory non-financial reporting for certain large undertakings. This directive represented one of the most significant regulatory developments in sustainability reporting (*Posadas et al. 2023*). The objective was to enhance the transparency and accountability of large companies in relation to sustainability and corporate social responsibility aspects by requiring information on environmental impacts, social and employee matters, anti-corruption measures and governance issues (*Manes-Rossi et al. 2018*). According to *Pizzi et al.* (*2022*), although the regulation primarily aimed at harmonisation and transparency, it also indirectly contributed to Sustainable Development Goal 12 (responsible consumption and production). However, the NFRD was criticised, as the non-financial disclosures provided by companies were often not comparable, reliable or relevant (*Faqih – Kramer 2024*).

[7] Based on the legislation in force on the date of submission of the study (30 June 2025). This study does not address the possible effects of the provisions of the Omnibus bill currently under discussion.
[8] https://eur-lex.europa.eu/eli/dir/2014/95/oj/eng

The CSRD replaced the NFRD and fundamentally transformed the European sustainability reporting framework by gradually expanding the scope of obliged entities and harmonising reporting formats to improve comparability (*Baumüller – Grbenic 2021; Faqih – Kramer 2024*).

In the first wave, public-interest large undertakings exceeding at least two of the following three criteria at the balance sheet date of the preceding financial year were required to prepare their first sustainability report for the 2024 financial year: total assets of at least EUR 25 million, net turnover exceeding EUR 50 million and an average number of employees of at least 500 during the financial year. As these companies were already subject to non-financial reporting under the NFRD, they had already accumulated several years of experience in sustainability reporting.

The regulation also standardises the content and format of sustainability reports to ensure comparability. On 31 July 2023, the European Commission adopted the European Sustainability Reporting Standards (ESRS), which govern corporate sustainability reporting. The standards aim to balance the reporting burden on companies with the objectives of the European Green Deal. They cover environmental, social and governance topics, including climate change and human rights.[9]

Furthermore, the directive requires mandatory assurance of sustainability reports. Auditors must provide an assurance opinion on whether the report complies with sustainability reporting requirements. In this context, the IAASB[10] issued ISSA 5000, a new international standard for sustainability assurance engagements, intended to provide a unified framework for verifying ESG data and enhancing reliability and transparency[11].

2.3.3. Hungarian legal background

In Hungary, the CSRD was implemented through amendments to the Hungarian Accounting Act and Act LXXV of 2007 on the Hungarian Chamber of Auditors, Audit Activities and Public Oversight of Auditors. The new provisions entered into force on 1 January 2024. To determine the personal scope of the regulation, it is necessary to define public-interest entities, as specified in Act LXXV of 2007 and further clarified by sector-specific legislation, including certain exemptions. In general, public-interest entities in Hungary include undertakings, whose transferable securities are admitted to trading on a regulated market of any Member State, as well as credit institutions and insurance undertakings. However, pursuant to Act CCXXXVII of 2013

[9] https://finance.ec.europa.eu/news/commission-adopts-european-sustainability-reporting-standards-2023-07-31_en
[10] International Auditing and Assurance Standards Board
[11] https://www.iaasb.org/focus-areas/understanding-international-standard-sustainability-assurance-5000

on Credit Institutions and Financial Enterprises, the Magyar Nemzeti Bank (MNB, the central bank of Hungary), MFB Hungarian Development Bank Private Limited Company and Hungarian Export-Import Bank Plc. are not public-interest entities.

3. Previous literature

Sustainability reporting has undergone significant development over the past decade, particularly as a result of European Union regulatory initiatives (NFRD, CSRD). Research primarily focuses on the effects of regulation, the role of institutional factors, differences between mandatory and voluntary reporting, and comparative analyses of European and international corporate sustainability reporting practices. The level and quality of sustainability reporting are significantly influenced by the institutional environment and legal framework (*Barakat et al. 2015*). The increasing harmonisation of disclosures is often explained by the three forms of institutional isomorphism—coercive, normative and mimetic (*Pizzi et al. 2023; Posadas et al. 2023; Stefanescu 2022; Tóth – Lippai-Makra 2024*). Examining German corporate practices, *Zülch et al.* (*2021*) concluded that sustainability reporting in Germany already partially aligns with CSRD requirements due to the country's strict corporate governance and sustainability standards. Comparing US and European sustainability reporting practices, *Soyombo et al.* (*2024*) found that industry standards and market pressure dominate in the United States, while in Europe mandatory regulation ensures more structured, comparable reporting.

Studies examining Hungarian sustainability reporting indicate that large companies are approaching compliance with European requirements, while small and medium-sized enterprises (SMEs) still face challenges. *Lippai-Makra et al.* (*2024*) analysed the sustainability reports of Hungarian large companies and found that subsidiaries belonging to corporate groups are closer to future regulatory requirements. Environmental factors were the most frequently reported topics, whereas anti-corruption activities were reported least frequently. Examining sustainability attitudes among Hungarian SMEs, *Surman and Böcskei* (*2023*) found that although companies perceive increasing pressure to implement sustainability measures, they primarily focus on economic sustainability. Analysing the integration of Sustainable Development Goals (SDGs), *Pizzi et al.* (*2022*) found that Hungary ranks 15th among European countries in terms of non-financial reporting related to SDG goals, and only 28.57% of companies integrate such information into their reports.

The importance of regulating sustainability disclosure is further highlighted by the active role of the MNB. Following the 2008 financial crisis, central bank mandates focused primarily on maintaining price stability and financial stability. Over time, as knowledge about the environmental impacts of climate change expanded and

sustainability challenges intensified, it became evident that the financial system is also exposed to significant risks. As a result, since 2021, the Act on the Magyar Nemzeti Bank has provided the MNB with a "green mandate" (*Deák – Sárvári 2023*). The MNB is among the few institutions in Europe with a statutory mandate to support environmental sustainability, while maintaining price stability as its primary objective (*Holczinger – Sárvári 2025; Kandrács et al. 2021*). *Gyura et al.* (*2023*) confirm the MNB's active role in promoting sustainability and its efforts to integrate sustainability considerations into the financial system. The findings presented by *Várgedő* (*2022*) indicate that climate-related risks relevant to banks are quantifiable and vary across institutions, reinforcing the justification for risk-based, standardised sustainability disclosure required by the CSRD. On 2 August 2022, the MNB issued Recommendation No. 10/2022 (VIII.2.) on climate-related and environmental risks and the integration of environmental sustainability considerations into the activities of credit institutions.[12] This recommendation outlines the MNB's expectations regarding banks' sustainability reports and presents related best practices. Its objective is to assist credit institutions in identifying, managing and disclosing climate-related and environmental risks, and in integrating environmental sustainability considerations into business activities. Through this, the MNB aims to enhance legal certainty and promote consistent application of relevant legislation.

4. Empirical research

Based on the above, the following research questions are formulated:

- *RQ1: How does the entry into force of the CSRD affect the sustainability disclosure intensity of obliged banks operating in Hungary?*
- *RQ2: How does the entry into force of the CSRD affect the sustainability disclosure practices of obliged banks operating in Hungary in terms of the form of disclosure?*
- *RQ3: Does the sustainability disclosure practice of obliged banks operating in Hungary become more similar as a result of the entry into force of the CSRD?*

4.1. Data

In our analysis, we examine banks operating in Hungary that were required to publish sustainability disclosures in the first wave of application. According to Section 177(97) of the Hungarian Accounting Act, public-interest banks are obliged to prepare a sustainability report if, in the two consecutive financial years preceding the business year, at the balance sheet date, at least two of the following thresholds

[12] https://www.mnb.hu/letoltes/10-2022-zold-ajanlas.pdf

were met: average number of employees exceeds 250, net sales revenue exceeds HUF 20 billion, total assets exceed HUF 10 billion, and additionally, the average number of employees in the given financial year exceeds 500.[13] To compile the list of banks operating in Hungary required to publish sustainability disclosures for the 2024 financial year, we used the institutional registry[14] and macroprudential data from the MNB.[15] In the first step, 28 banks were identified in the registry. Branches, credit guarantee institutions and one specialised savings institution were excluded. Subsequently, pursuant to Act CCXXXVII of 2013 on Credit Institutions and Financial Enterprises,[16] MFB Hungarian Development Bank Plc. and Hungarian Export-Import Bank Plc. were excluded from the analysis, as the law explicitly excludes them from the category of public-interest credit institutions. After completing the above steps, 14 public-interest banks were identified in Hungary. These 14 banks were then screened based on size criteria. Data on total assets, net sales revenue and number of employees for 2022 and 2023 were downloaded from the Crefoport database.[17]

Based on the statutory size criteria, it was established that seven banks operating in Hungary were required to publish a sustainability report for the 2024 financial year (*Table 1*).

Table 1
List of Hungarian banks obliged for the 2024 financial year

1.	CIB Bank Zrt.
2.	ERSTE BANK HUNGARY Zrt.
3.	Kereskedelmi és Hitelbank Zrt.
4.	MBH Bank Nyrt.
5.	OTP Bank Nyrt.
6.	Raiffeisen Bank Zrt.
7.	UniCredit Bank Hungary Zrt.

4.2 Research methodology

In this study, we apply content analysis to examine changes in the sustainability disclosure practices of banks operating in Hungary which are obliged to report under the CSRD. Content analysis is a frequently used method for collecting and analysing narratives derived from various documents and is widely applied in the analysis

[13] https://net.jogtar.hu/jogszabaly?docid=a0000100.tv
[14] https://intezmenykereso.mnb.hu/
[15] https://statisztika.mnb.hu/publikacios-temak/felugyeleti-statisztikak/penz--es-hitelpiaci-szervezetek/hitelintezeti-aktualis-publikaciok
[16] https://net.jogtar.hu/jogszabaly?docid=a1300237.tv. Downloaded: 2 June 2025.
[17] https://www.crefoport.hu/

of sustainability reports (*Dissanayake 2020*). We follow the process outlined by *Krippendorff* (*2004*), according to which content analysis consists of several steps. First, the units of analysis must be defined, which may include words, sentences or themes. Subsequently, categories are created to organise and classify the data. The next step is coding, during which text segments are assigned identifying codes to facilitate analysis. The reliability of the analysis must then be examined to ensure consistency of the results. Finally, data interpretation is carried out, which may involve statistical or qualitative methods.

In our case, the phenomenon under examination is the sustainability disclosure practice of banks, specifically the impact of the entry into force of the CSRD and the mandatory application of the ESRS. Therefore, sustainability reports published for the 2023 and 2024 financial years were analysed. In the case of sustainability reporting, unlike financial reporting, group-level consolidated reports exempt subsidiaries from preparing individual reports. Consequently, certain entities operating in Hungary do not publish individual sustainability reports. In line with international practice (*Remlein – Romić 2025*), and in order to ensure comparability, we examined the group-level consolidated reports in all cases.

4.2.1. Coding procedure

For coding, we applied the item list used by *Dumitru et al.* (*2017*), based on *Lippai-Makra* (*2025*). This ensures that the results of the present study are comparable with previous findings, thereby allowing a comparison of the impact of the NFRD and the CSRD on bank sustainability disclosures. The coding process is described below:

The list developed by *Dumitru et al.* (*2017*) consists of 20 non-financial disclosure items divided into four categories (*Table 2*). These items were identified in the sustainability reports during coding. The scoring system reflecting the type of disclosure is as follows: 0 points – no disclosure regarding the given item; 1 point – the item is presented in textual form; 2 points – the item is supported by a key performance indicator or other numerical data; 3 points (2+1) – the item includes both textual description and numerical data. Accordingly, the maximum achievable score per report is 60 (20 × 3), with higher scores indicating higher disclosure intensity.

Table 2
Non-financial items for the empirical analysis

I. Business model, policies, risks related to CSR issues
1. Business model – brief description
2. Policies related to environmental, social and employee matters, respect for human rights, anti-corruption and bribery matters
3. Principal risks related to environmental, social and employee matters, respect for human rights, anti-corruption and bribery matters
4. Non-financial KPIs
II. Environmental matters
1. Impacts on the environment
2. Impacts on health and safety
3. Use of renewable energy
4. Use of non-renewable energy
5. Greenhouse gas emissions
6. Water withdrawal
7. Air pollution
III. Social and employee-related matters
1. Actions taken to ensure gender equality
2. Implementation of the fundamental conventions of the International Labour Organization (ILO)
3. Working conditions
4. Respect for employees' right to information and consultation
5. Respect for trade union rights
6. Health and safety at work
7. Dialogue with local communities
8. Actions taken to ensure the protection and development of local communities
IV. Ethical matters
1. Tools to prevent human rights violations, combat corruption and bribery
Source: Dumitru et al. (2017: p. 304)

4.2.2. Construction of disclosure indices

To construct the disclosure indices, we applied the methodology used by *Dumitru et al.* (*2017*). Following their approach, four indices were calculated for each examined company and for both financial years, based on the items assigned to each category and the maximum achievable score per category.

The indices were constructed as follows:

$$I_1 = \left(\frac{P_1}{12}\right) * 100 \quad (1)$$

$$I_2 = \left(\frac{P_2}{21}\right) * 100 \quad (2)$$

$$I_3 = \left(\frac{P_3}{24}\right) * 100 \quad (3)$$

$$I_4 = \left(\frac{P_4}{3}\right) * 100 \quad (4)$$

where *P* denotes the total score assigned to the items within the given category.

To evaluate overall sustainability disclosure intensity, we also calculated the following combined index:

$$I_{combined} = \frac{(I_1 + I_2 + I_3 + I_4)}{4}. \quad (5)$$

To measure disclosure intensity, we also applied an alternative scoring system based on *Lippai-Makra* (*2025*). The aim was to examine how the results are affected by alternative weighting.

Following *Li et al.* (*2008*), the scoring was modified to include graphical representations in addition to textual and numerical disclosures (including charts and explanatory figures, but excluding illustrative photographs and decorative images). Accordingly, the scoring was modified as follows: 0 points – no disclosure regarding the given item; 1 point – the item is presented in textual form; 1 point – the item is supported by a key performance indicator or other numerical data; 1 point – the item includes graphical representation. With this alternative scoring method, the maximum score per item remains 3 points, and the maximum score per report remains 60 points. Achieving the maximum score indicates that the reporting entity disclosed textual, numerical and graphical information for all 20 examined items.

Based on the combined index, disclosure intensity was categorised as follows:

- 0 – no non-financial disclosure,
- 1–30% – low disclosure level,
- 31–70% – medium disclosure level,
- 71–100% – high disclosure level.

As a result of the coding, category-level and overall sustainability disclosure indices were calculated for each of the seven examined banks for both the 2023 and 2024 financial years.

5. Results

We present the comparison of disclosure intensities (*Figure 1 and Table 3 in the Appendix*) below. As described above, two weighting methods were used to determine disclosure intensity, which are referred to as follows:

- A weighting according to *Dumitru et al.* (*2017*),
- B weighting according to *Li et al.* (*2008*).

In 2023, i.e. the last year of application of the NFRD, five banks reached a high disclosure intensity level according to the A weighting method, whereas in 2024 only one bank achieved this level. Following the entry into force of the CSRD, disclosure intensity decreased for five banks and increased for two banks. For all banks classified in the high-intensity category in 2023, the level decreased to medium in 2024. Among those showing an increase, only one bank moved into the high-intensity category. According to the B weighting method, disclosure intensity increased for three banks and decreased for four. In 2023, six banks exhibited medium disclosure intensity, while in 2024 all seven banks fell into the medium category (*Figure 2*). Based on the summary of results, it can be concluded that disclosure intensity, as measured by the examined items, shows an overall decline following introduction of the CSRD. However, the magnitude of change between the two years varies across banks (*Figure 2*). In other words, the impact of the CSRD is not uniform across institutions.

Figure 1
Disclosure intensity of banks in 2023 and 2024 according to the two weighting methods

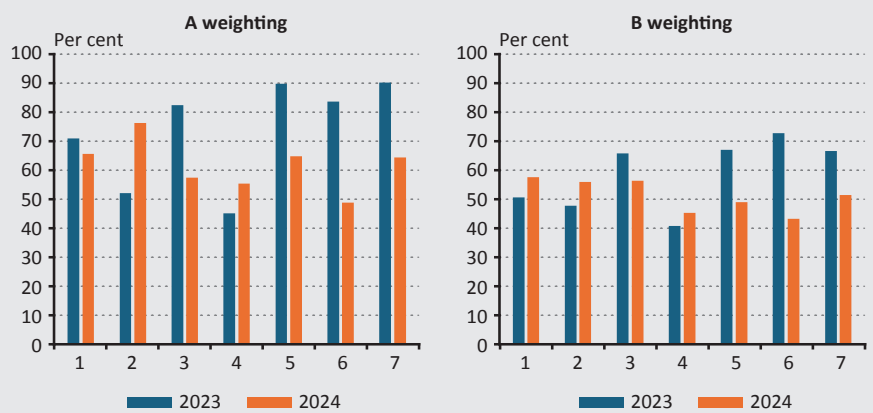
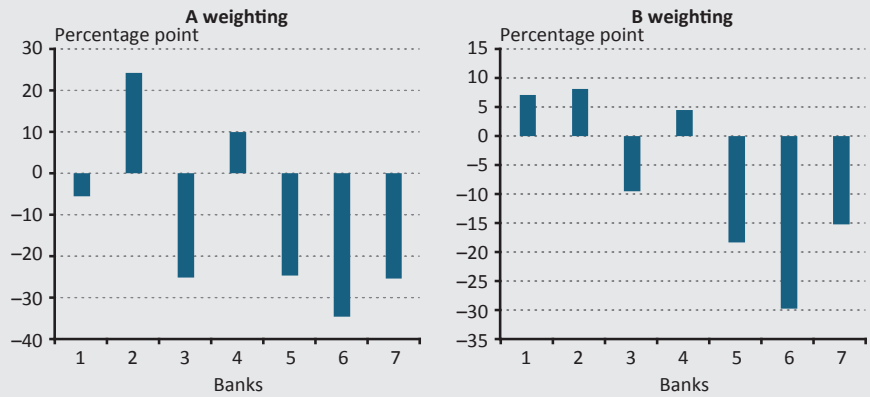
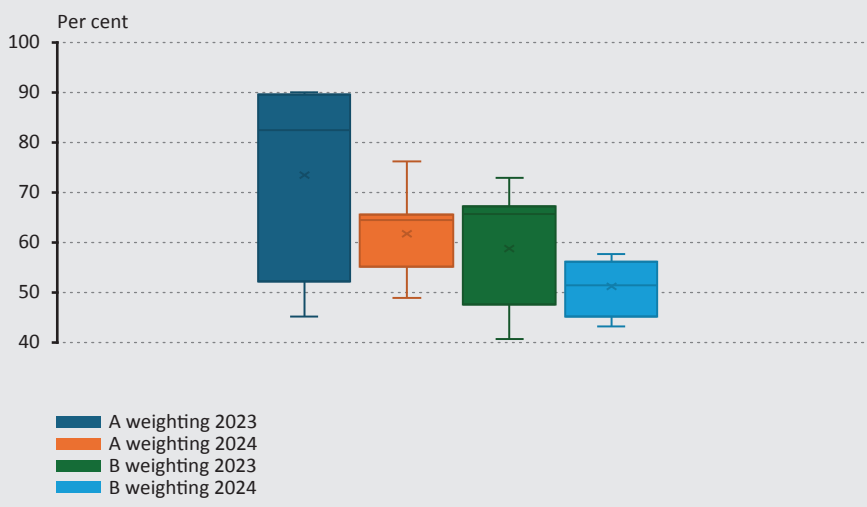


Figure 2
Change in disclosure intensity of banks in 2024 compared to 2023



Further examination of the results indicates that although the regulation reduced disclosure intensity based on the examined parameters, it also had positive effects (*Figure 3 and Table 4 in the Appendix*). Following the entry into force of the CSRD, the dispersion of disclosure intensity decreased (both the standard deviation and the interquartile range decreased in percentage points). In other words, sustainability disclosure practices became more similar across companies, meaning that standardisation achieved its intended effect. Reports prepared in accordance with the CSRD are more homogeneous than those prepared under the previous framework. These findings support the presence of normative isomorphism.

Figure 3
Convergence of disclosure intensity of banks by weighting and year



Based on the decline in disclosure intensity, it cannot be unequivocally concluded that the CSRD reduced the overall amount of information disclosed to stakeholders. Rather, the form and thematic focus of disclosures changed compared to those prepared under the NFRD. If disclosure had been examined using a different item list – for example, based on thematic ESRS standards or the mandatory disclosure elements required therein (policies, actions, metrics, targets) – it is possible that an increase in disclosure intensity could have been detected. Therefore, the conclusion regarding decreased disclosure intensity must be qualified by noting that the decline is observable specifically with respect to NFRD-oriented disclosure items among obliged Hungarian banks. The results also indicate that different weighting methods influence outcomes. Consequently, applying multiple weighting approaches strengthens the robustness of conclusions if the results point in the same direction.

5.1. Additional findings

Qualitative content analysis allows observations beyond quantifiable results. Based on the analysis, the 2024 reports contain more explanatory narrative content and are structured more systematically, largely due to ESRS requirements. This trend enhances comparability across reports. It can also be observed that the 2024 reports contain fewer numerical data points. While this research does not provide a definitive explanation, this phenomenon may be related to the stricter audit methodology applied to the entire sustainability report. Further interview-based research is recommended to examine this assumption. Regarding the format of reports, in 2023 two banks published standalone sustainability reports, whereas in 2024 all banks, in accordance with the regulation, published sustainability disclosures as part of the management report within the annual report. In May 2025, when downloading reports, we found that one bank also published a short summary highlighting sustainability performance alongside the annual report.

In terms of accessibility, sustainability and annual reports were easily available on the official websites of all examined banks. In most cases, the websites also explicitly highlighted the introduction of CSRD-compliant disclosure practices. With regard to applied sustainability reporting standards, a marked shift can be observed. While in 2023 all seven examined banks reported in accordance with GRI[18] standards, in 2024 all seven reported in accordance with the mandatory ESRS standards. Although this shift was expected, it is noteworthy that none of the banks published a complete GRI index table at the end of the report, and only one bank presented entity-specific disclosures using explicitly referenced GRI indicators.

Regarding assurance, in 2023 one bank did not subject its sustainability report to audit. By 2024, however, all seven banks' sustainability reports included auditor assurance opinions, and all were audited by Big Four audit firms. One interesting

[18] Global Reporting Initiative.

observation is that while in 2023 only four banks declared that their climate targets had been validated by professional organisations (e.g. SBTi, PCAF), in 2024 six banks did so. This change is not necessarily directly attributable to regulation; it is likely driven by investor expectations. Interview-based research would be useful to explore this further.

6. Summary and outlook

In summary, based on the analysis, the research questions can be answered as follows:

RQ1: How does the entry into force of the CSRD affect the sustainability disclosure intensity of obliged banks operating in Hungary?

The impact of the CSRD's entry into force can be clearly identified in the sustainability disclosure practices of obliged banks operating in Hungary. Disclosure intensity has changed and, overall, has decreased. However, this decrease in intensity does not imply that stakeholders have access to less information overall. The results indicate that the form of disclosure has changed, shifting in favour of narrative, i.e. textually descriptive sections, at the expense of numerical and graphical information. These changes can be explained by the narrative-centred requirements of the ESRS, which on the one hand prescribe fewer numerical data points than the previously most widely used standards, and on the other hand grant exemptions from the disclosure of several numerical data points during the first three years of application of the standard.

RQ2: How does the entry into force of the CSRD affect the sustainability disclosure practices of obliged banks operating in Hungary in terms of the form of disclosure?

With regard to the form of disclosures, it can be established that the emphasis has shifted toward narrative disclosures compared to numerical data reporting. This result can partly be attributed to the above-mentioned characteristics of the ESRS and presumably also to changes in audit methodology. Previously, during the audit of sustainability reports, not all numerical data were examined for substantiation, meaning that companies could, for example, disclose estimated data. Thus, the tightening of audit requirements may also have reduced the amount of numerical data that can be presented. However, this aspect was not examined in this study.

RQ3: Does the sustainability disclosure practice of obliged banks operating in Hungary become more similar as a result of the entry into force of the CSRD?

The reports have become more similar both in form and in content. Thus, from this perspective, the regulation already achieved its objective in its first year

of application. The answer to the above research question supports normative isomorphism, meaning that as a result of regulation, disclosure practices converge.

6.1. Central bank policy implications

Based on the research conducted, several recommendations can be formulated that allow for utilisation of the results by the central bank. At the outset of the research, we encountered several definitional and regulatory interpretation difficulties, the clarification and understanding of which may assist banks operating in Hungary in complying with legal requirements. Therefore, we propose that the following issues be presented in an accessible manner on the MNB's website and in publications addressed to banks.

One such issue concerns the determination of public-interest entity status. Given that clarifying this question requires the joint interpretation of several legal acts (*Lippai-Makra 2025*), it would be advisable to publish a summary of these interpretations. In our view, in agreement with the reasoning of *Lippai-Makra* (*2025*), MFB Hungarian Development Bank Private Limited Company and Hungarian Export-Import Bank Plc. do not qualify as public-interest entities. Therefore, we recommend reviewing the information displayed in the institutional search tool available on the MNB's website[19] and indicating the status of banks excluded from the category of public-interest entities under the Credit Institutions Act[20] in accordance with the law.

Another issue concerns the clarification of the concept of net sales revenue in the case of banks. Most European Union and national regulations related to sustainability disclosure link disclosure obligations to revenue thresholds to some degree. According to Section 95/D (6) of the Hungarian Accounting Act, in the case of credit institutions, annual net sales revenue corresponds to the income defined in Article 43(2)(c) of Council Directive 86/635/EEC. It would be worthwhile to elaborate on this definition on the MNB's website and in publications addressed to banks, as well as to consult with various company information service providers to ensure that the appropriate amounts are reflected in their databases.

The results of this research support the immediate, direct impact of regulation on disclosure practices, which may serve as an argument for the introduction of regulation at the level of binding legislation rather than recommendations. However, the current European Union and domestic regulatory and standard environment is continuously evolving, posing challenges for obliged entities. Therefore, only those elements that are durable and contain long-term requirements should be elevated to the level of legislation. It may be more appropriate to focus on updating

[19] https://intezmenykereso.mnb.hu/Details/Index?LId=276&EntityType=Institute&expandAccordions=IntezmenyAlapadatok
[20] https://njt.hu/jogszabaly/2013-237-00-00

green recommendations. Furthermore, the fact that all examined obliged entities complied with the new legal requirements also supports prioritising the updating of green recommendations rather than expanding them from a legal compliance perspective. Introduction of the CSRD and mandatory application of the ESRS have shifted disclosure practices toward extensive narrative reporting. Processing these textual sections is difficult and time-consuming for stakeholders. Therefore, it may be recommended to publish a clear, concise and informative summary of sustainability reports, possibly tailored to the information needs of specific stakeholder groups (e.g. investors, creditors, employees, business partners, etc.). We identified a best practice in this regard at one Hungarian bank. The credibility of such short summaries is supported by the audited sustainability report.

It may also be advisable to incorporate the criteria of double materiality assessment defined in the ESRS, as well as the definitions of impacts, risks and opportunities, into the recommendations. Current recommendations focus primarily on climate change (adaptation and mitigation); however, with the emergence of thematic ESRS standards and the increasingly broad application of the Taxonomy Regulation, other environmental topics (e.g. water management, biodiversity, etc.), as well as social and governance aspects, are gaining prominence. These could be illustrated with practical examples in green recommendations, for instance through the best practices observed in the 2024 sustainability reports. It may also be worth reconsidering the currently recommended minimum ten-year time horizon and aligning it with the time horizons defined in the European Union's Sustainable Finance Action Plan and the ESRS. Furthermore, it would be advisable to examine the consistency between the CSRD/ESRS framework, Act CVIII of 2023 and the MNB's green recommendations.

6.2. Research limitations

The limitations of the present research primarily stem from the applied methodology. Qualitative content analysis requires significant research resources, which limits the number of reports that can be analysed within a given period. In the coming years, an increase in the number of obliged entities is expected, which may make it difficult to examine the entire population. Another methodological limitation arises from the selected item list. As mentioned earlier, the item list developed by *Dumitru et al.* (*2017*) is NFRD-focused; the use of a different item list may yield different results. Furthermore, the applied weighting method may also influence the results. Another methodological limitation is that steps 1 and 5 of the sustainability disclosure process cannot be examined solely through the analysis of reports. Finally, since several entities make use of the exemption allowing them not to prepare individual sustainability reports due to group-level consolidated reporting, the results may not fully reflect Hungarian specificities.

6.3. Future research directions

The above research limitations may be addressed through the following future research directions. The high demand for research resources could be mitigated by the use of artificial intelligence-based text analysis solutions capable of learning contextual interpretation, thereby overcoming criticisms raised against traditional, non-AI-based text analysis software. One such AI-based solution is Briink,[21] which is specifically designed for the analysis of sustainability disclosures.

In order to gain a comprehensive understanding of the entire disclosure process, this research could be complemented by in-depth interviews, which would allow the assessment of motivational factors related to step 1 and stakeholder feedback associated with step 5. Interviews could also reveal the extent to which obliged banks relied on the MNB's green recommendations when developing their disclosure strategies. Moreover, in-depth interviews provide insight into how sustainability considerations are integrated into corporate processes. The flexible, open-ended format of interviews facilitates a deeper understanding of individual perspectives, decision-making processes and challenges that a structured questionnaire might not fully capture. Additionally, the interview setting can foster an atmosphere of trust, encouraging honest and detailed responses regarding banks' sustainability efforts and their actual impacts (*Gyulavári et al. 2017*).

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[21] https://www.briink.com/

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Appendix

Table 3
Disclosure intensity of banks by year and weighting

A weighting								
		1	**2**	**3**	**4**	**5**	**6**	**7**
2023	I_1	42%	67%	100%	50%	100%	100%	100%
	I_2	76%	71%	76%	48%	71%	81%	86%
	I_3	67%	38%	54%	50%	88%	54%	75%
	I_4	100%	33%	100%	33%	100%	100%	100%
	$\mathbf{I_{combined}}$	**71%**	**52%**	**83%**	**45%**	**90%**	**84%**	**90%**
	disclosure level	high	medium	high	medium	high	high	high
2024	I_1	67%	83%	67%	67%	100%	67%	100%
	I_2	100%	76%	71%	67%	43%	67%	67%
	I_3	63%	46%	58%	54%	83%	29%	58%
	I_4	33%	100%	33%	33%	33%	33%	33%
	$\mathbf{I_{combined}}$	**66%**	**76%**	**57%**	**55%**	**65%**	**49%**	**65%**
	disclosure level	medium	high	medium	medium	medium	medium	medium
B weighting								
		1	**2**	**3**	**4**	**5**	**6**	**7**
2023	I_1	33%	67%	83%	50%	83%	100%	33%
	I_2	52%	57%	71%	38%	52%	71%	17%
	I_3	50%	33%	42%	42%	67%	54%	42%
	I_4	67%	33%	67%	33%	67%	67%	8%
	$\mathbf{I_{combined}}$	**51%**	**48%**	**66%**	**41%**	**67%**	**73%**	**67%**
	disclosure level	medium	medium	medium	medium	medium	high	medium
2024	I_1	58%	67%	75%	58%	67%	58%	75%
	I_2	81%	52%	67%	48%	33%	52%	48%
	I_3	58%	38%	50%	42%	63%	29%	50%
	I_4	33%	67%	33%	33%	33%	33%	33%
	$\mathbf{I_{combined}}$	**58%**	**56%**	**56%**	**45%**	**49%**	**43%**	**51%**
	disclosure level	medium	medium	medium	medium	medium	medium	medium

Table 4
Convergence of disclosure intensity of banks

	A weighting 2023	A weighting 2024	B weighting 2023	B weighting 2024
Mean	74%	62%	59%	51%
Lower quartile	52%	55%	48%	45%
Median	83%	65%	66%	51%
Upper quartile	90%	66%	67%	56%
Interquartile range	38pp	10pp	20pp	11pp
Standard deviation	17pp	8pp	11pp	5pp
Minimum	45%	49%	41%	43%
Maximum	90%	76%	73%	58%

Note: pp: percentage points

Comparison of Capital Adequacy Rules for Credit Institutions and Investment Firms*

László Seregdi – Nikolett Kovácsné Bóta

Capital adequacy requirements play a key role in the current prudential regulatory system for the financial sector, both for credit institutions and investment firms. This study summarises how the system of requirements has developed, which elements are similar for credit institutions and investment firms, what the differences are, and what justifies them. It is also examined whether the capital requirement regulatory system for investment firms has become more effective, as a result of the special framework based specifically on the particular risks of investment firms that was developed for them starting in 2021. Finally, the paper also discusses possible directions in which capital requirements regulation may further evolve in these sectors.

Journal of Economic Literature (JEL) codes: F38, G21, G24, G28, N24

Keywords: capital adequacy, credit institutions, investment firms, prudential regulation

1. Introduction

One exciting issue related to financial sector regulation over the past thirty years has been whether the prudential regulation of credit institutions and investment firms should be the same or different. The main arguments in favour of harmonisation are that credit institutions and investment firms engage in similar activities, and in doing so they take on similar risks, and that different capital adequacy requirements may give rise to competitive advantages or disadvantages in individual sectors, which may lead to undesirable market effects in the long term. In addition, credit institutions themselves provide investment services or own investment firms, and it is simpler for them if they can calculate capital requirements for these activities using the same method as for financial services. However, the rationale for applying different capital adequacy requirements lies in the fact that while in the case of

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credit institutions the vast majority of risks arise from lending activities and thus primarily take the form of credit risk, in the case of investment firms, as they only provide credit to a limited extent and within a narrow scope, their risks mainly take the form of market and operational risk. As regulations have evolved, the focus has shifted from one side to the other, and thus before we go into more detail on the arguments and observable effects, we begin with a brief historical overview showing the sometimes divergent and sometimes convergent development paths of credit institutions and investment firms.

2. Development of capital adequacy requirements for credit institutions and investment firms

2.1. 1980s and 1990s – the beginnings

In the case of banks, own funds and risk-based own funds requirements came to the fore at the end of the 1980s, when the Basel Committee on Banking Supervision published its famous Basel I recommendations in July 1988. On the one hand, Basel I defined in detail the components and conditions of banks' own funds and, on the other hand, it prescribed which banking risks should be taken into account and what methods should be used to calculate capital requirements. The main reason for the establishment of the Basel Committee and the publication of the recommendations was that, starting in the 1970s, the international nature of financial services had become increasingly strong, making it necessary to define internationally accepted minimum requirements that would be capable of preventing or at least anticipating the emergence of crisis situations at individual banks (*Kandrács et al. 2018*). Given that uniform application of such requirements across Europe was already of paramount importance at that time due to the common banking market, in 1989 the European Economic Community implemented the Basel Committee's recommendations through two directives.[1] However, these directives only applied to credit institutions. At that time, no uniform European capital requirements had yet been defined for investment firms.

One significant change was brought about by Council Directive 93/6/EEC of 15 March 1993 on the capital adequacy of investments firms and credit institutions. The main reason for issuing the new directive was that Council Directive 93/22/EEC of 10 May 1993 on investment services in the securities field enabled investment firms authorised and supervised in the EEC to establish branches and provide services freely in other Member States. Opening of the single market also made it necessary to establish a uniform set of requirements for investment firms. The main innovation of Directive 93/6/EEC was that it laid down detailed methods for

[1] Council Directive 89/299/EEC of 17 April 1989 on the own funds of credit institutions; Council Directive 89/647/EEC of 18 December 1989 on a solvency ratio for credit institutions.

calculating capital requirements for the market risks of banks and investment firms, with particular emphasis on position risk, counterparty credit risk/settlement risk and foreign exchange risk. Prior to this, the capital adequacy requirements for banks were based almost exclusively on credit risk, while no uniform capital requirements had been specified for investment firms. Accordingly, Directive 93/6/EEC can be regarded as the starting point to which the rules for calculating capital requirements for credit institutions and investment firms were linked.

However, Directive 93/6/EEC also introduced a number of other important harmonisation requirements in the area of prudential regulation of investment firms. It laid down initial capital requirements which are essentially still in force today, but at that time, in the absence of the euro, they were set at ECU 50,000, ECU 125,000 and ECU 730,000, depending on the activities for which the investment firm was authorised (under the current Directive, these are set at EUR 75,000, EUR 150,000 and EUR 750,000, and thus although the classification criteria have changed somewhat since then, they have not increased significantly in 30 years). In addition, Directive 93/6/EEC required also investment firms to apply the same large exposure regime as banks and laid down rules for supervision on a consolidated basis. Directive 93/6/EEC is considered by Member States to be the predecessor of the current MiFID and, in accordance with Council Directive 93/22/EEC of 10 May 1993 on investment services in the securities field, had to be transposed into national legislation by 31 July 1995, with Member States to apply the rules from 1 January 1996.

The rules in Directive 93/6/EEC defining the calculation of capital requirements for market risks were primarily based on the Basel Committee's recommendations on the same topic, which was published in its final form in 1996,[2] which means that they were developed primarily on the basis of the activities and risks of credit institutions. The Directive and the Basel recommendations introduced two significant changes to the calculation of capital requirements, which also had a major impact on the rules currently in force. First, they introduced the concept of the trading book into the regulations, dividing the positions of banks and investment firms into those held by institutions for the short term for trading purposes and those held for the longer term for investment purposes. This distinction is important because, while credit risk remains significant in the case of assets held for investment purposes (i.e. in the case of a bond, whether the issuer will be able to repay the capital raised upon maturity), in the case of positions taken for trading purposes, the fluctuations of market factors (interest rates, foreign exchange, exchange rates) must be taken into account when calculating capital requirements, as these determine whether the institution will realise a profit or loss on a given position. In the case of positions recorded in the trading book, another new feature

[2] Amendment to the capital accord to incorporate market risks: https://www.bis.org/publ/bcbs24.htm

was that they had to be valued at market value on a daily basis in order to ensure that the resulting profits and losses were properly reported.

It is interesting to note that the rule still in force today, according to which investment firms must have own funds equivalent to at least one-quarter of their fixed overheads for the previous year, was already included in this Directive published in 1993, which is noteworthy because, as also mentioned later in this study, the vast majority of investment firms still use this indicator, which cannot be considered risk-sensitive at all, to determine their final capital adequacy requirement.

Another significant change in the regulatory framework occurred with an amendment to Directive 93/6/EEC in 1998, which – in line with the 1996 Basel recommendations on the calculation of capital requirements for market risks – allowed institutions, with the permission of the supervisory authorities, to calculate their market risk capital requirements not only using a standardised approach, but also by applying internal models developed by themselves. This conceptual shift was introduced for credit risk only later, with the publication of the Basel II framework in 2004. The applicability of internal models was therefore first tested in the case of market risks and was subsequently extended more broadly.

2.2. 2006 – New EU Directives

The next major milestone in the capital adequacy regulation of credit institutions and investment firms came in 2006, when two important new directives were issued, replacing the EU legislation previously in force. Directive 2006/48/EC of the European Parliament and of the Council of 14 June 2006 relating to the taking up and pursuit of the business of credit institutions (CRD) essentially dealt with the prudential regulation of credit institutions, the conditions for taking up and pursuit of the business, and the freedom to provide services; it also included the method for calculating own funds and the capital requirements for credit risk and operational risk. In line with the Basel II recommendations published by the Basel Committee in 2004, the latter already allowed banks to calculate capital requirements based on internal models and required supervisory authorities to set individual additional capital requirements for banks under the SREP procedure, if necessary. Another requirement arising from Basel II was the establishment of detailed disclosure requirements for banks.

Another important EU directive adopted in 2006 was Directive 2006/49/EC of the European Parliament and of the Council of 14 June 2006 on the capital adequacy of investment firms and credit institutions, which repealed Directive 93/6/EEC. Directive 2006/49/EC laid down the initial capital requirements for investment firms and, taking over the provisions of Directive 93/6/EEC, regulated the calculation of

capital requirements for market risks. Directives 2006/48/EC and 2006/49/EC were closely interconnected, *inter alia*, because of the following:

- Directive 2006/48/EC stipulated for credit institutions that were required to keep a trading book to apply the market risk capital requirement calculation set out in Directive 2006/49/EC;
- investment firms were similarly required to calculate capital requirements for credit risk and operational risk in accordance with the rules set out in Directive 2006/48/EC;
- institutions with low trading book exposures could also calculate their market risk capital requirements in accordance with Directive 2006/48/EC;
- investment firms had to calculate their own funds in accordance with Directive 2006/48/EC; and
- Directive 2006/49/EC also incorporated those elements of the Basel II recommendations that allowed supervisory authorities to impose additional capital requirements and introduced detailed disclosure requirements.

Directives 2006/48/EC and 2006/49/EC essentially follow the Basel II recommendations, but there are some differences, as pointed out by *Radnai* and *Vonnák* (*2010*). In their opinion, one of the most important differences is that the Basel II recommendations only apply to large banks operating internationally, while the provisions of the above Directives apply to European credit institutions as well as investment firms. Due to the difference in the scope of application, several detailed provisions in the Directives have been amended, for example, certain rules have been relaxed so that compliance with the requirements would not impose a disproportionate burden on smaller institutions.

2.3. 2013 – CRD/CRR

Adoption of the new CRD/CRR[3] framework in 2013 was a significant milestone in the harmonisation of capital adequacy requirements for credit institutions and investment firms. The fact that the rules defining capital adequacy requirements were transferred from the level of directives to the level of regulations was in itself a significant step forward, as this made them directly applicable in the Member States and prevented Member States from implementing them in a way that would give their own markets a competitive advantage. According to *Tajti* (*2011*), implementation also provided an opportunity to harmonise domestic regulations applicable to credit institutions and investment firms, i.e. to reduce regulatory differences between sectors. Mandatory, uniform and direct implementation also

[3] CRD: Capital Requirements Directive CRR: Capital Requirements Regulation.

enabled the use of a number of other new instruments that would not have been able to function properly under the previous system, such as:

- many detailed rules were laid down in the form of European Commission regulations;
- the European Banking Authority (EBA) was able to develop a Q&A system providing further guidance on the practical application of the rules; and
- the EBA was able to issue guidelines setting out common supervisory expectations for institutions operating in the EU, or setting out supervisory methodologies that can be applied uniformly by the national supervisory authorities of all Member States.

In addition, EU policymakers decided in 2013 to set uniform capital requirements for credit institutions and investment firms in the CRR. This was also reflected in the title of the regulation, and the preamble to the CRR (2) specifically refers to the European Council's decision of 18–19 June 2009, which stated that a single European rulebook applicable to all credit institutions and investment firms in the internal market was also necessary.

Since one of the fundamental objectives of the CRR was the EU-level implementation of the Basel III recommendations issued by the Basel Committee in 2010, and partly included regulatory responses to the 2008 global financial crisis, it remained true that investment firms also had to operate under a capital adequacy regime that was essentially based on the specific characteristics of banking activities. There was a significant difference in the initial capital requirements, as the CRD set an initial capital requirement of EUR 5 million for credit institutions, while for investment firms it retained the previous initial capital requirements, which remained at EUR 50,000, 125,000, or EUR 730,000, depending on the type of investment firm. The CRR itself contained minor differences for investment firms: for example, groups of investment firms were exempt from the application of capital requirements on a consolidated basis, and investment firms carrying out simpler activities could apply simpler capital requirement calculation methods, but the basic principle was uniform capital requirements regulation for credit institutions and investment firms.

2.4. 2019 – IFR/IFD

In 2019, the IFR[4] and IFD[5] were adopted, which fundamentally changed the prudential regulation of investment firms and effectively separated them from the requirements for credit institutions. According to the preamble to the IFR, this was necessary primarily because the CRR rules were designed based on the specific characteristics of credit institutions' activities and were not fully applicable to investment firms. Unlike credit institutions, most investment firms do not pose a systemic risk that would require overly detailed requirements to be imposed on them. Furthermore, they differ from each other in terms of size and activities, so it is appropriate to develop differentiated rules for them. The new rules applicable to investment firms from 2021 are essentially based on the following main principles:

- they take much greater account of the specific characteristics and risks of investment firms' activities than before;
- large investment firms (Class 1) must continue to comply with the CRR requirements, while medium-sized firms (Class 2) have a separate capital requirement framework that takes into account the specific characteristics of investment firms, while the smallest investment firms (Class 3) that perform simple activities must comply with a simplified set of requirements;
- the capital requirement calculation is based on the typical risks of investment firms, in particular the risk arising from exposures to clients, the risk arising from market exchange rate movements, and the risks arising from the operation of the investment firm; and
- the new regulation remains linked to the CRR, so that, for example, the concepts of own funds and many others are the same as those used in the CRR, and investment firms are given the option calculate their capital requirements based on the CRR instead of the IFR.

However, one important change following transition to the IFR/IFD framework was that the capital buffer requirements previously applicable to investment firms under CRD provisions were abolished, while the supervisory review and evaluation process (SREP) applied under Pillar 2, the possibility of imposing specific additional capital requirements in connection with it, and the Pillar 2 guidance tool remained in place.

[4] Regulation (EU) 2019/2033 of the European Parliament and of the Council of 27 November 2019 on the prudential requirements of investment firms and amending Regulations (EU) No 1093/2010, (EU) No 575/2013, (EU) No 600/2014 and (EU) No 806/2014

[5] Directive (EU) 2019/2034 of the European Parliament and of the Council of 27 November 2019 on the prudential supervision of investment firms and amending Directives 2002/87/EC, 2009/65/EC, 2011/61/EU, 2013/36/EU, 2014/59/EU and 2014/65/EU.

The EBA and ESMA[6] also issued joint guidelines on the methodology to be applied in the SREP process for investment firms.[7]

Starting in 2021, the prudential requirements for credit institutions and investment firms was once again separated. The similarities and differences that remain between the capital requirement calculation systems for credit institutions and investment firms are summarised in *Table 1*.

Table 1
Similarities and differences between the capital adequacy calculation rules for credit institutions and investment firms

Similarity	Credit institutions	Investment firms
Calculation of own funds is essentially the same	Capital requirement calculation is primarily based on credit risk	Capital requirements are also calculated on the basis of fixed overheads and initial capital requirements
Pillar 2 and capital guidance	Applicability of internal credit risk models	K-factors
Disclosure requirements	Capital buffers (capital conservation, countercyclical, systemic risk, systemic importance)	There are no capital buffer requirements
Initial capital requirements may also be a minimum level	Uniform capital requirement system	Different capital requirements depending on the specific characteristics of the investment firm (Class 1, 2, 3)
Investment firms may choose to comply with the rules set out in the CRR	Based on the specific characteristics of banking risks	Based on the specific characteristics of investment firm risks
To be met not only at individual level, but also at group level	Prudential consolidation	Possibility of group capital testing for simple groups
Quantitative requirements are supplemented by corporate governance requirements	Supplemented by detailed liquidity requirements (LCR, NSFR)	Supplemented by simplified liquidity requirements

Note: LCR: Liquidity Coverage Ratio, NSFR: Net Stable Funding Ratio

In the second part of the study, we primarily examine the extent to which actual data of credit institutions and investment firms support the need for this amendment.

[6] European Securities and Markets Authority.
[7] Joint EBA and ESMA Guidelines on common procedures and methodologies for the supervisory review and evaluation process (SREP) under Directive (EU) 2019/2034, EBA/GL/2022/09, ESMA35-36-2621, 20 July 2022.

3. Proportions of risks determining the capital requirements of credit institutions and investment firms

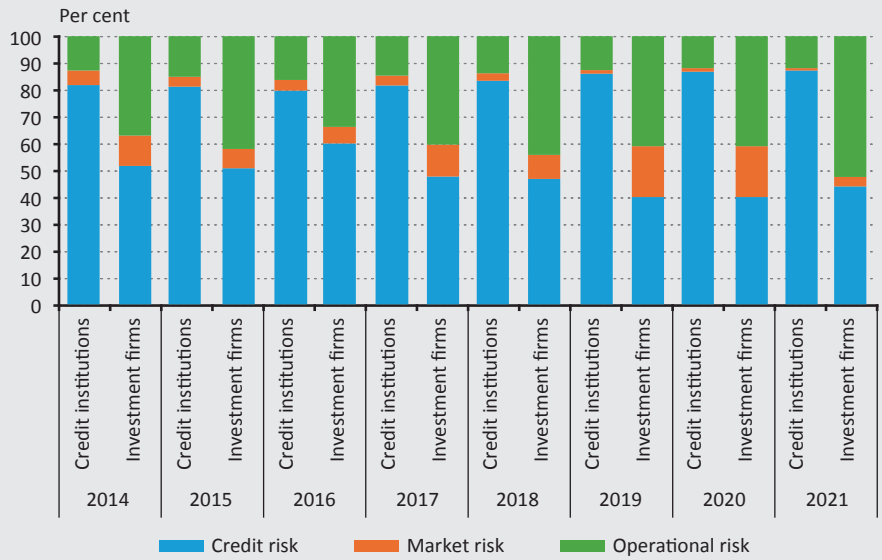
The development of the IFR and IFD rules was a long process. One important milestone in this was the EBA opinion prepared at the request of the European Commission (Call for Advice), in which the EBA summarised its recommendations that should be taken into account in the development of prudential rules for investment firms based on its analysis (*EBA 2015*). In its opinion, the EBA noted that there are very large differences between investment firms in terms of their activities and corporate risks, and therefore a number of exemptions had to be developed for them in the CRD/CRR framework. The EBA therefore recommended to the European Commission that these differences be taken into account in the prudential regulation of investment firms, by classifying investment firms into three groups (Class 1, 2, 3). Another important finding of the EBA opinion is that, for investment firms not covered by the CRR, the principles of proportionality and risk sensitivity justify the development of a new capital requirement calculation framework that better reflects the specific characteristics of investment firms' operations.

The different risk profiles of credit institutions and investment firms are easy to see when we look at the activities they perform. The three most important activities of credit institutions are lending, deposit-taking, and account management and related payment services. From the perspective of capital requirement calculation rules, lending is therefore the most important activity (deposit-taking and account management have more of an impact on liquidity requirements), so in the case of banks, credit risk accounts for the vast majority of capital requirements.

In the case of investment firms, capital requirements depend largely on the activities carried out by the investment firm in question. The main considerations here are whether the investment firm carries out trading on own account, manages client money, provides investment loans, etc. However, since the main activity of investment firms is not lending, their risks differ significantly from those of credit institutions.

To illustrate this, we examined the risks determining the capital requirements of credit institutions and investment firms during the period when investment firms also calculated their capital requirements under the CRR (2014–2021). Supervisory disclosure requirements require national supervisory authorities to publish sector-level statistical data on the institutions they supervise. Under the disclosure requirements, capital requirements must be broken down by credit risk, operational risk and market risk. Based on data published by the MNB, the distribution of these risks for domestic credit institutions and investment firms is shown in the chart below (*Figure 1*).

Figure 1
Breakdown of capital requirements for credit institutions and investment firms by risk type (CRD/CRR) (2014–2021)



Source: Compiled based on supervisory disclosures by the MNB

Figure 1 clearly shows that while the share of credit risk in the total capital requirement for credit institutions consistently remained between 79 and 87 per cent, the corresponding figures for investment firms ranged between only 39 and 59 per cent. The difference is also clearly visible in the share of operational risk, which ranged between 11 and 16 per cent for credit institutions and between 33 and 51 per cent for investment firms, clearly showing that operational risk has a much more significant impact on capital requirements for investment firms than in the case of credit institutions. As regards the share of market risk within capital requirements, this ranges from 0 to 4 per cent for credit institutions, but from 3 to 19 per cent for investment firms, meaning that market risks also have a proportionally greater impact on the capital requirements of investment firms than on those of credit institutions.

Overall, it can thus be concluded that the relative proportions of the types of risk determining the capital requirements of credit institutions and investment firms differ significantly, and while credit risk is of decisive importance in the case of credit institutions, operational and market risk have a much greater impact on the capital requirements of investment firms in terms of proportions.

The main reason for this is that there is a significant difference between the activities of credit institutions and investment firms, as credit institutions predominantly risk depositors' money by granting loans, while investment firms primarily execute client orders when managing funds received from clients and may only engage in speculative transactions on their own account, meaning that their losses also originate from other sources. From a regulatory perspective, another significant difference is that while the risks of credit institutions are primarily reflected in their balance sheets and thus also affect the liquidation assets in the event of liquidation, the client assets managed by investment service providers are not included in the company's balance sheet and are not part of the liquidation assets. This difference also has an impact in that while credit institutions face a high risk of contagion to other businesses and, consequently, systemic risk, this risk is lower for investment firms.

4. Comparison of capital adequacy ratios for credit institutions and investment firms under the CRD/CRR and IFR/IFD frameworks

Under the IFR capital requirement calculation framework, the capital requirement for investment firms classified as Class 2 is the highest of the following three amounts:

- the minimum initial capital requirement;
- a quarter of the fixed overheads calculated on the basis of the previous year's activity;
- the sum of the capital requirements (K-factors) determined for the investment firm on the basis of the risk factors established in accordance with the IFR.

The capital requirement calculation is simpler for investment firms in Class 3, which must meet the higher of the permanent minimum capital requirement or one-quarter of the fixed overheads calculated on the basis of the previous year's activity.

Table 2 shows the system of K-factors used in the capital requirement calculation method based on risk factors for investment firms.

Table 2
Types and content of K-factors

Category	K-factor	K-factor content
RtC (Risk-to-Client) Risk affecting clients	**K-AUM** (Assets Under Management)	Takes into account the risk of losses that may affect clients as a result of improper discretionary management of client portfolios or poor-quality execution.
	K-CMH (Client Money Held)	Takes into account the risk of potential losses that may arise from the investment firm holding its clients' money.
	K-ASA (Assets Safeguarded and Administered)	Covers risks related to the safekeeping and administration of client assets.
	K-COH (Client Orders Handled)	Covers the risk of losses arising from the execution of client orders (on behalf of the client, not on behalf of the investment firm) by the investment firm.
RtM (Risk-to-Market) Risk affecting the market	**K-NPR** (Net Position Risk)	The net position risk arising from the investment firm's own-account activity or from the execution of client orders on behalf of the investment firm, for which the capital requirement is calculated in accordance with the CRR.
	K-CMG (Clearing Margin Given)	An alternative method to K-NPR that can be used if the investment firm conducts trading on own account through clearing members.
RtF (Risk-to-Firm) Risk affecting the firm	**K-TCD** (Trading Counterparty Default)	Capital requirement for the investment firm's exposure to default by its trading counterparties.
	K-CON (Concentration Risk)	Based on concentration risk arising from large exposures to individual counterparties.
	K-DTF (Daily Trading Flow)	Due to operational risk arising from the investment firm's daily trading turnover.

Source: Dakó et al. (2022)

The EBA has published additional information on the capital adequacy data of investment firms operating in the EU, using data published by national supervisory authorities. This includes, among other things, the role that the individual K-factors play in determining the capital requirements of investment firms.[8] This data is presented in *Figure 2*. For better clarity, we have rearranged the data published by the EBA based on the proportion of RtC within the total capital requirement.[9] The chart clearly shows that there are significant differences in the capital requirement structures in individual countries, and there is no uniform EU experience with regard to K-factors. There are two countries (Austria and Latvia) where RtC accounts for 100 per cent of capital requirements, while there is also a country (Spain) where this K-factor accounts for only 1 per cent of total capital requirements.

[8] It should be noted that the final capital requirement for a given investment firm may be based not only on the capital requirement calculated using K-factors, but also on the capital requirement calculated using initial capital or fixed overheads.
[9] Slovenia's data are not included in the chart because they only provided partial data.

The share of market risk is also highly variable, with the highest share in the Netherlands (86 per cent), but also above 70 per cent in Portugal and Ireland. As far as risk affecting the firm is concerned, it plays a particularly important role in Cyprus and Malta. The data for Hungarian investment firms largely reflect the EU average, together with the data for French and German investment firms.

Figure 2
Distribution of K-factor requirements of investment firms (IFR) (2023)

Source: Compiled based on EBA (2024a)

Figure 3 shows the development of the average capital adequacy ratio of domestic credit institutions and investment firms between 2014 and 2025. During this period, the capital adequacy ratios of credit institutions and investment firms remained roughly at the same level. The capital adequacy ratio of credit institutions fluctuated steadily between 17 and 20.8 per cent, while that of investment firms was similar in magnitude, albeit with much greater volatility, with extremes of 19.6 per cent and 47.3 per cent.[10] In her study, *Füstös* (*2016*) highlights that the capital adequacy ratios of Hungarian banks improved significantly between 2003 and 2016 Q3, mainly due to the continuous tightening of capital requirement regulations.

Since investment firms have been no longer calculating their capital requirements based on the CRR but on the IFR since 2021, the data of investment firms must be transformed to a value similar to the credit institution method in order to ensure that capital adequacy calculated according to the CRR and the IFR is comparable. This is necessary because, whereas under the CRR the capital adequacy ratio is

[10] Between the end of 2019 and the end of 2020, the calculated capital adequacy ratio of investment firms increased significantly, which can be explained primarily by the emergence of a new, significant market player. The same applies to the exceptionally high capital adequacy ratios "calculated" according to the IFR until the end of 2023. By the end of 2020, sector-level own funds had increased by 129.44 per cent compared to the end of the previous year, while total risk exposure had increased by only 24.68 per cent.

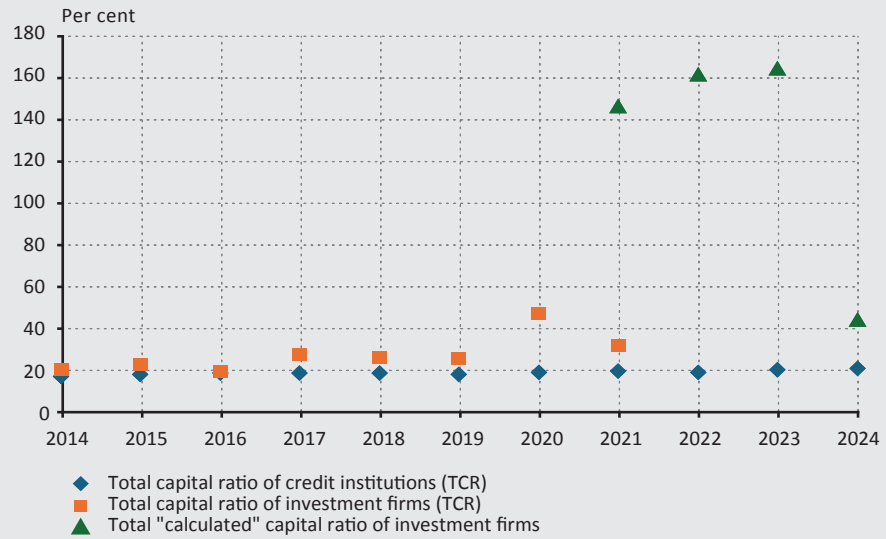
calculated by dividing own funds by the total risk exposure value, under the IFR the capital adequacy ratio is calculated as the ratio of available own funds to capital requirements. In order to make these two values comparable, we multiplied the capital requirement for investment firms by 12.5, as this value approximates the total risk exposure value used in the CRR.

Looking at the capital adequacy ratios published from 2021 onwards, it can be seen that with the introduction of the IFR, the calculated capital adequacy ratios of investment firms differ significantly from those of credit institutions, exceeding them several times over and even reaching values that would be considered almost irrational for a credit institution. In these years, the average calculated capital adequacy ratio of investment firms fluctuated between 44 and 164 per cent, mainly due to the composition effect. While at the end of 2014 there were still 23 investment firms operating in Hungary that submitted supervisory reports, by the end of 2021 there were only 12, and by the end of 2024 their number had dropped to just 9.[11]

Between 2021 and 2023, the extremely high capital adequacy ratio of domestic investment firms was primarily due to the unique effect of the presence of a market participant with special characteristics. This participant had an international background and belonged to a global corporate group, which operated with an exceptionally high capital adequacy ratio in itself. The impact of this was also reflected in the sector-level data. This market player withdrew from the market in 2024, and this market restructuring had a significant impact on the development of the national average capital adequacy ratio. It should also be noted that although the period from 2021 to 2023 should be used as a basis for assessing the impact of the introduction of the IFR, there were a number of other factors during this period (Covid, war, inflation shock) that also influenced the capital adequacy ratio of investment firms. According to the methodological notes published by the MNB on prudential statistical time series (*MNB 2025b*), the majority of Hungarian investment firms do not engage in trading on own account; their business model is dominated by intermediary activities, which is why their capital adequacy significantly exceeds the regulatory minimum requirement. However, due to the different sizes and business models of individual investment firms, there are significant differences in individual capital adequacy. To illustrate these differences, the prudential statistical capital adequacy time series published by the MNB provide institutional values in a tiered manner according to capital adequacy, in addition to the number of institutions.

[11] Source: MNB prudential statistical publications.

Figure 3
Capital adequacy of credit institutions and investment firms in Hungary (2014–2021)

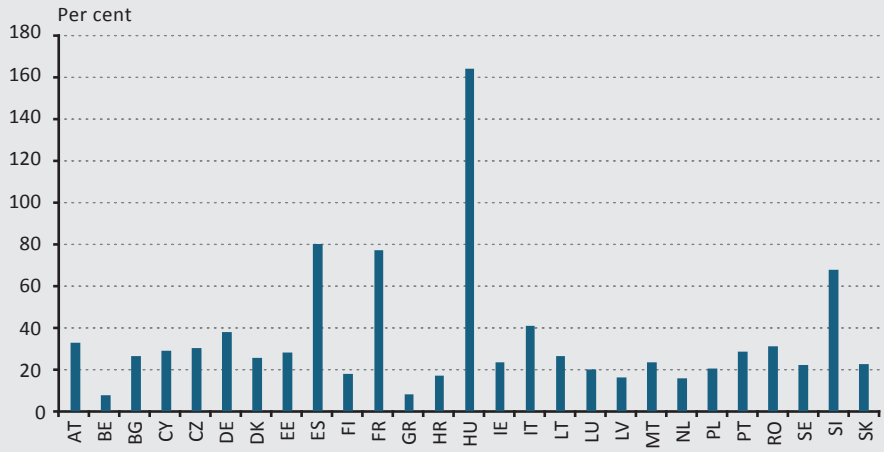


Source: Compiled based on the MNB's prudential statistical publications

Examining the calculated capital adequacy ratios of investment firms by EU Member State (*Figure 4*), it is clear that at the end of 2023 the Hungarian capital adequacy value for investment firms was exceptionally high, as most Member States were within the 20–40-per cent range, subject to significant variation depending on the business model of the investment firms. A detailed analysis covering all EU Member States showing the impact of the introduction of the IFR on capital requirements has not yet been performed, but in their study covering Italian investment firms, *Capone et al.* (2024) used empirical data from supervisory reporting to conclude that the new capital requirement calculation rules introduced by the IFR, which are better tailored to and more sensitive to the specific risks of investment firms, resulted in lower capital requirements, particularly for investment firms engaged in more complex activities (Class 2) and larger-size investment firms.

This leads to the conclusion that the capital requirements calculated using the K-factors in the IFR do not significantly restrict the risk-taking of investment firms in several countries (e.g. Estonia, France and Slovenia) and have a much lower deterrent effect than in the case of credit institutions, while in other EU Member States these values are closer to the capital adequacy ratios typical of credit institutions. To complete the picture, it should be added that by 2024 the average calculated capital adequacy ratio of Hungarian investment firms had also fallen to 33.8 per cent, mainly due to the withdrawal of one major service provider from the Hungarian market; nevertheless, this value remains exceptionally high (*MNB 2025a*).

Figure 4
Calculated average capital adequacy ratio of investment firms in 2023 in individual EU Member States



Source: Compiled based on EBA (2024b)

As mentioned earlier, the capital requirement framework for investment firms also differs from that for credit institutions in that it is determined by the higher of three values: the initial capital requirement, one-quarter of the fixed overheads of the preceding year, or the capital requirement according to K-factors. *Table 3* shows which factor represents the bottleneck, i.e. the final capital requirement, for each investment firm.

At the same time, it is also clear that only about 9.4 per cent of all investment firms listed in *Table 3* (207/2199) had a capital requirement calculated by the K-factors that was the final capital requirement. Even in the case of investment firms operating as financial groups and thus calculating consolidated capital requirements, 77.7 per cent (143 out of 184) have their final capital requirement determined by one-quarter of the fixed overheads of the preceding year. The only difference is that while the K-factor capital requirement ranks second among the factors determining the final capital requirement for investment firms calculating consolidated capital adequacy, for investment firms calculating capital requirements on an individual basis, the ongoing minimum capital requirement represents a larger proportion.

Table 3
Number of investment firms by method of determining final capital requirements at the end of 2023 at the EU level

	Number of investment firms – on an individual basis			Number of investment firms – on a consolidated basis			Total
	Class 2	Class 3	Total	Class 2	Class 3	Total	
Fixed overhead requirement (FOR)	438	865	1,303	94	49	143	1,446
Permanent minimum capital requirement (PMCR)	255	271	526	12	8	20	546
K-factor requirement (pcs)	186	–	186	21	–	21	207
Total	**879**	**1,136**	**2,015**	**127**	**57**	**184**	**2,199**

Note: The EBA notes in the consultation document that not all investment firms and their data are included in the table; the total number of investment firms operating in the EU at the end of 2023 was 2,262.

Source: EBA (2024b)

All of these figures show that, although the capital requirements calculated according to the K-factors were indeed developed taking into account the specific characteristics of investment firms, in practice they cannot effectively fulfil one of the main objectives of setting capital requirements, namely to limit the amount of risks that institutions can take on. The capital requirement calculated according to the K-factors represents an excessively low capital requirement in relation to the own funds of investment firms under the current calibration, which means that the final capital requirement for investment firms is determined primarily not by the K-factors, but rather by fixed overheads or ongoing minimum capital requirements. This situation cannot be considered optimal because, of the three possible methods, the capital requirement based on K-factors is clearly the most risk-sensitive, and so the ideal situation would be for investment firms' capital requirements to be determined primarily by this method, with the other two methods serving only as a kind of backstop, such as the leverage ratio in the case of credit institutions.

However, in assessing the effectiveness of K-factors, it should also be taken into account that the method used to determine the final capital requirement for Class 2 investment firms (FOR, PMCR or K-factor) fundamentally depends on the size and activity profile of the investment firm, and thus the low proportion of K-factor firms is not necessarily or exclusively due to undercalibrated factor coefficients or the insufficient accuracy of certain K-factors.

5. Possible directions for further development

Pursuant to Article 60 of the IFR, the EU Commission, after consulting with the EBA and ESMA, shall conduct a review and, where appropriate, submit a legislative proposal to the European Parliament and the Council, which shall also address the adequacy of the K-factor capital requirement calculation provisions. In September 2024, the EBA also published a consultation paper presenting the state of prudential compliance of investment firms, setting out possible areas for further development and posing questions to market participants (*EBA 2024b*). Based on the comments received, the EBA revised its proposals and published them in October 2025, this time jointly with ESMA (*EBA 2025*).

In their final proposals, the EBA and ESMA consider the categorisation of investment firms in the IFR/IFD framework (Class 1, 2, 3) as fundamentally correct and effective, but identified a number of legal provisions that are not entirely clear and therefore need to be clarified or revised (e.g. the definition of thresholds used for classification, their combined application).

The final report raises the possible review of the capital requirement based on one-quarter of annual fixed overheads. As noted earlier, this rule was already included in Directive 93/6/EC, and its underlying rationale is that an investment firm should be able to continue operating for at least three months even in a crisis situation, so that crisis management or liquidation proceedings can be conducted during that period. Although the EBA raised the possibility in the consultation paper that this three-month period could possibly be extended, the final report states that, based on the comments received and the analyses carried out, the EBA and ESMA consider that it remains appropriate and applicable to all types of investment firms, without distinction based on their activities. The final report also contains detailed proposals for modifying the items that can be deducted when calculating fixed overheads. Currently, a separate European Commission regulation governs the scope of these deductible items,[12] which should be reviewed in line with the proposals.

In addition, the EBA and ESMA reviewed the current framework of K-factors and its possible shortcomings. For example, the K-CoH factor, which measures the risks arising from client orders, does not include the risks arising from the investment service “Placing of financial instruments without a firm commitment basis”. In the case of the K-AUM factor, which measures risks arising from asset management, it would be worth reviewing the definition of investment advice of an ongoing nature. The EBA and ESMA consider it necessary to review and define more accurately the calibration of the capital requirement for operational risk arising from daily

[12] Commission Delegated Regulation (EU) 2022/1455 of 11 April 2022 supplementing Regulation (EU) 2019/2033 of the European Parliament and of the Council with regard to regulatory technical standards for own funds requirement for investment firms based on fixed overheads.

trading activity (K-DTF), as it may result in lower capital requirements in some cases, while the use of the capital requirement for concentration risk (K-CON) is limited by the IFR to financial instruments in the trading book of investment firms, excluding instruments outside the trading book from its scope, which may result in an inaccurate assessment of actual risk concentrations for Class 2 firms. In addition to these issues, the EBA and ESMA report also identified a number of risks that are not currently fully covered by the K-factors, such as non-trading book exposures, including crypto asset exposures.

In its consultation paper, the EBA also raised the possibility of making the application of FRTB rules mandatory for investment firms belonging to Class 2. In 2019, the Basel Committee issued its recommendations on the renewal of market risk capital requirement calculations, which were named the Fundamental Review of Trading Book. The EU adopted the FRTB rules in CRR3, making them mandatory for credit institutions, but their implementation was ultimately postponed until 2027. Preliminary surveys showed that the FRTB rules would significantly increase the market risk capital requirements for credit institutions. In their final report, the EBA and ESMA recommend that the application of the FRTB should not be mandatory for Class 2 investment firms, but only optional.

Although the EU Commission specifically requested EU authorities to make proposals on ESG issues during the review of prudential regulation of investment firms, the final report of the EBA and ESMA only refers back to the EBA report published in 2023 (*EBA 2023*), in which it expressed its view that capital requirement calculation should remain risk-based in relation to ESG risks, i.e. preferential capital requirements may only be granted or additional capital requirements imposed for ESG risks if this is also justified by risk analyses.

6. Conclusions

In summary, a number of factors justified the decision to differentiate the capital adequacy requirements for investment firms from those for credit institutions. Investment firms engage in different types of activities, have different risk structures and do not carry the same systemic risk as credit institutions. However, the capital adequacy requirements set out in the IFR, which have been applied from 2021, and the related implementing regulations are not yet final, are currently under review and in many cases need to be supplemented or recalibrated. In their current form, the capital adequacy requirements do not adequately fulfil their role of limiting investment firms from taking excessive risks and have different effects on investment firms following different business models. Overall, however, investment firms in the European Union and Hungary operate with high capital adequacy ratios and operate safely, and the review of the regulations aims to ensure that this situation continues in the long term.

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Spinning Jennies and Silicon: The Economics of Innovating or Evaporating – Creative Destruction and Public Policies*

Balázs Égert

This paper reviews the contributions of the 2025 Nobel Prize in Economics laureates, Joel Mokyr, Philippe Aghion and Peter Howitt, to our understanding of innovation-driven economic growth, situating their work within the broader evolution of modern growth theory and empirical evidence. It highlights why the Industrial Revolution marked a transition to sustained, self-reinforcing technological progress and shows how Mokyr's emphasis on knowledge, culture and institutions complements Aghion and Howitt's Schumpeterian framework, which formalises innovation as a competitive process of firm entry, exit and technological replacement. The paper then uses these frameworks to interpret the widespread productivity slowdown observed in advanced OECD economies since the mid-2000s, arguing that weakened creative destruction, slower diffusion of frontier technologies, declining business dynamism and policy headwinds are key explanatory factors.

Journal of Economic Literature (JEL) codes: O30, O40, O43, L16, N10

Keywords: innovation, productivity, economic growth, creative destruction, institutions

1. Introduction

Economic growth, one of the most central concepts in economics, reflects an economy's capacity to produce more goods and services over time, thereby improving living standards and creating opportunities for social progress. Sustained growth expands income, employment and public resources, enabling societies

* 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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to invest in education, health, infrastructure and innovation. It can also support fiscal sustainability, as a growing economy generates higher tax revenues without increasing tax rates. At the same time, economic growth remains a key policy objective, not only for its material benefits but also because the manner in which it is achieved shapes broader social and environmental outcomes. Policymakers must balance the pursuit of higher output with concerns about inequality, environmental degradation and long-term resilience.

Economic growth has long stood at the core of economic research, both theoretical and empirical. Over the decades, several Nobel Prize laureates, from Solow and Romer to North, Krugman and Acemoglu, have sought to uncover the mechanisms driving long-run growth. Building on this tradition, the 2025 Economics Nobel Prize winners, *Joel Mokyr*, *Philippe Aghion* and *Peter Howitt* have made particularly influential contributions to our understanding of the central role of innovation in modern economic development. Their work sheds light on why innovation lies at the heart of productivity and growth, and how the interaction between institutions, technology, competition and entrepreneurship shapes both the pace and the direction of economic progress.

This article appraises the contributions of Joel Mokyr, Philippe Aghion and Peter Howitt by tracing how the analysis of innovation has evolved from the neoclassical emphasis on capital accumulation to an endogenous theory of technological progress. It first discusses their core contributions. The paper begins with Mokyr's explanation of why the Industrial Revolution triggered a more than two-century-long phase of self-sustaining, innovation-led growth, in sharp contrast to earlier, short-lived episodes of technological advance. It then turns to Aghion and Howitt's formalisation of Schumpeter's process of creative destruction, through which new firms and technologies continually displace older, less productive ones. Building on these foundations, the paper highlights key stylised facts that illustrate the empirical relevance of their ideas and shows how their frameworks remain highly informative for understanding the prolonged productivity slowdown observed in many advanced OECD economies. It also considers other complementary factors and policies shaping innovation outcomes, before concluding with a discussion of policy options to reignite innovation, productivity and long-term economic growth.

2. Economic growth in the economics literature

Modern growth theory starts with Solow (*Nobel 1987*): output rises through factor accumulation, physical capital, labour and human capital, but long-run growth ultimately comes from total factor productivity (TFP). "Productivity isn't everything, but in the long run it is almost everything" has become an often-cited

sentence in modern economics (*Krugman 1994*). Lucas (*Nobel 1995*) formalised the role of human capital accumulation and externalities; Arrow (*Nobel 1972*) introduced "learning-by-doing"; and Romer (*Nobel 2018*) made innovation and ideas endogenous, showing how R&D, knowledge spillovers and scale effects can sustain growth.

Trade and FDI enter as engines and conduits: openness raises competitive pressure and market size. Krugman's new trade and economic geography (*Nobel 2008*) showed how scale economies, knowledge spillovers and market size could drive productivity growth and sustain increasing return. FDI and global value chains diffuse technology and managerial know-how across borders, feeding TFP.

Institutions shape all of these channels. Following Acemoglu, Johnson and Robinson (*Nobel 2024*), economic and political institutions – such as property rights and the rule of law – have a decisive impact on why some countries are rich and others poor. Nobel work by Douglass North (*Nobel 1993*) and Elinor Ostrom (*Nobel 2009*) explains how rules, enforcement and collective governance reduce transaction costs and enable cooperation, while Simon Kuznets (*Nobel 1971*) highlighted structural transformation, e.g. the shift from agriculture to industry/services, as a hallmark of modern growth.

The consensus is clear: while factor accumulation initiates development, sustained prosperity depends on TFP growth, which in turn rests on innovation, human capital, openness and strong institutions. Innovation is a key driver of economic development and growth because it fuels productivity, competitiveness and long-term prosperity.[1] By creating new products, processes and technologies, innovation allows firms to produce more efficiently and meet evolving consumer needs. It enables economies to move up the value chain, generate high-quality jobs and adapt to structural changes, such as digitalisation and the green transition. Beyond boosting output, innovation also fosters knowledge spillovers, ideas and techniques that spread across sectors, magnifying its impact on overall growth. In essence, innovation transforms resources and talent into sustained economic progress.

Yet innovation can only flourish under certain conditions. The 2025 Economics Nobel laureates elaborated these conditions. Joel Mokyr (*Nobel 2025*) explained why the Industrial Revolution marked the beginning of more than two centuries of persistent economic growth fuelled by innovation, unlike earlier episodes where technological advances yielded only temporary gains. His work highlighted the role of an open, knowledge-based culture and supportive institutions, and the

[1] Aghion & Howitt's and Mokyr's accounts of innovation focus mainly on frontier innovations. However, most countries grow primarily by diffusing and adapting existing technologies, which supports convergence toward the technological frontier.

connection between theoretical advancement in science with practice-oriented engineering in transforming invention into real-life products and thus into sustained productivity growth. Philippe Aghion and Peter Howitt (*Nobel 2025*) formalised the Schumpeterian process of creative destruction to explain how innovation arises from competition among firms and drives long-run productivity growth since the late 1940s.

3. Innovation in the empirical growth literature

Empirical growth research has developed along three main strands, each mapping directly to the theoretical drivers of growth: factor accumulation, innovation, total factor productivity (TFP) and institutions. First, growth and development accounting provide the quantitative foundation. Growth accounting (*Solow 1957*) decomposes changes in output over time into the contributions of capital deepening, labour input and a residual capturing TFP growth. This approach shows that while capital accumulation explains much of short-run growth, sustained improvements in living standards require persistent gains in TFP, consistent with Solow and Romer's emphasis on technological progress and innovation. Development accounting, by contrast, explains cross-country income level differences by comparing factor inputs and productivity levels at a given point in time. Studies such as *Hall and Jones* (*1999*) show that even large cross-country differences in physical and human capital cannot fully explain income gaps, leaving TFP as the dominant source of divergence in prosperity. Together, these accounting exercises bridge theory and evidence: factor accumulation drives early growth, while long-run divergence stems from differences in innovation, efficiency and institutional quality.

Second, cross-country econometric analyses, such as the *Barro – Sala-i-Martin* (*2003*) conditional convergence framework, investigate the determinants of growth across nations. These studies confirm that, controlling for structural factors, poorer countries tend to grow faster, but the speed of convergence depends critically on education, institutional quality, trade openness and macroeconomic stability. Later refinements explicitly bring in innovation and technology diffusion (R&D, patents, adoption) and suggest that growth determinants interact rather than operate in isolation (*Comin – Hobijn 2010*).[2]

[2] They also highlight non-linearities and threshold effects: for example, the returns on education or openness rise sharply only beyond certain institutional or human-capital thresholds. Cross-country panels and instrumental-variable approaches (e.g. *Acemoglu et al. 2001*) further establish the causal role of inclusive institutions, consistent with the theoretical insights of North, Ostrom, Acemoglu and Robinson on governance and incentives.

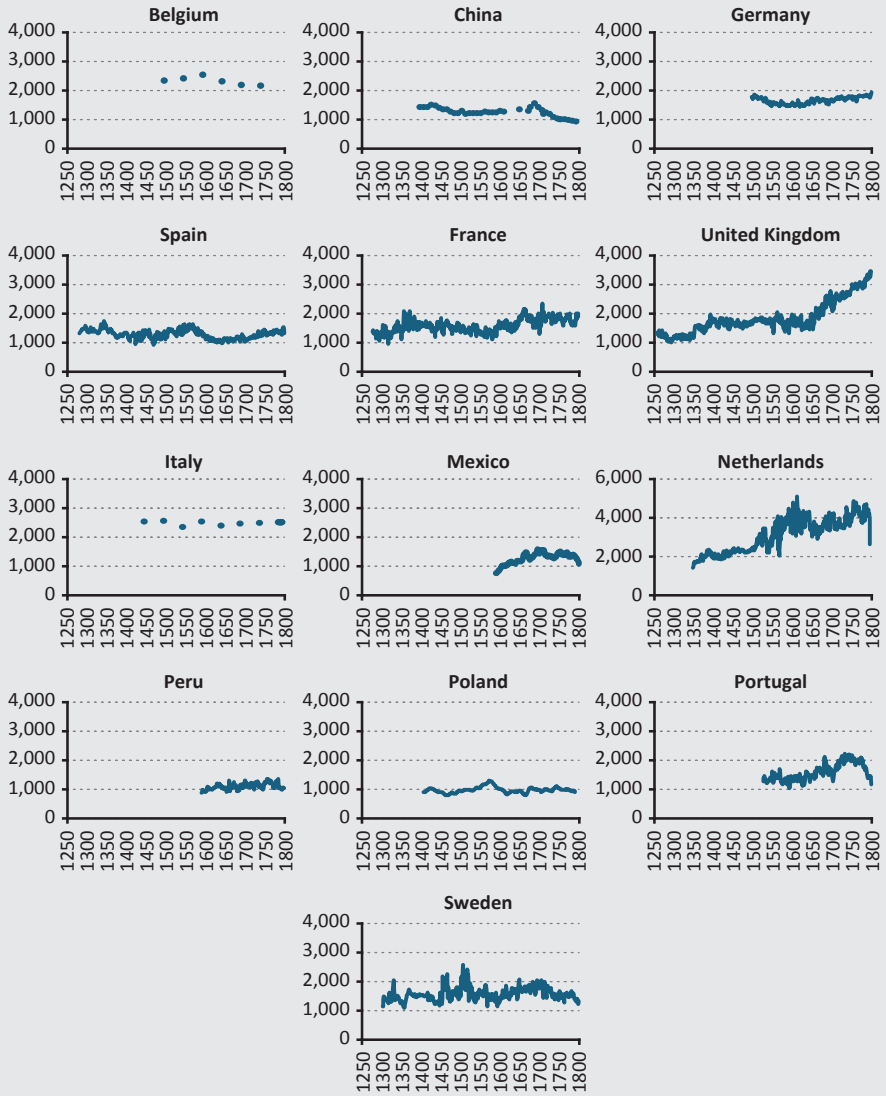
Third, micro-based productivity and innovation studies connect aggregate patterns to firm-level behaviour. Using plant- and firm-level data, research by *Hsieh – Klenow* (*2009*) and others shows that misallocation of capital and labour, driven by regulatory barriers, credit frictions or weak institutions, accounts for large cross-country productivity gaps. Other work exploits firm-level R&D, patent and trade data to demonstrate that innovation raises productivity both directly and through knowledge spillovers, and that human capital enhances the ability to absorb and adapt foreign technologies (*Crépon et al. 1998; Jaffe et al. 1993; Bloom et al, 2013; Griffith et al. 2003*). Experimental evidence from Banerjee, Duflo and Kremer (*Nobel 2019*) further highlights how micro-level constraints in credit, education and governance aggregate into slower factor accumulation and weaker innovation at the macro level.

All three strands converge on the conclusion that while factor accumulation initiates growth, only innovation, efficient reallocation and strong institutions can sustain it in the long run.

4. Innovation, productivity and growth since the Industrial Revolution

For most of Europe's ancient and medieval history, technological progress was real but sporadic. Innovations such as Gutenberg's printing press, mill power and early scientific instruments including the telescope, microscope, barometer, thermometer and precision clocks, did appear, but they arrived in isolated bursts. They rarely accumulated or reinforced one another, and temporary increases in productivity were typically followed by a return to stagnation. The historical Maddison dataset shows that per capita incomes remained broadly flat for centuries. For example, per capita income in Spain was not significantly different in the 13th and 14th centuries compared with the 17th century. Similarly, economic development in 17th-century France was not substantially different from that in the mid-1300s. Other countries with long-run data available, such as Belgium, China, Germany, Italy and Poland, display similar patterns. Britain and the Netherlands, however, provide notable exceptions. The Netherlands experienced a significant rise in economic prosperity during the 16th century, reflecting the boom in international trade, while in Britain, per capita income began to rise gradually from the mid-17th century, indicating an early shift in economic power (*Figure 1*).

Figure 1
Evolution of per capita income from 1250 to 1800 (2011 PPP-adjusted USD)



Source: Maddison Project Database 2023 (https://www.rug.nl/ggdc/historicaldevelopment/maddison/releases/maddison-project-database-2023)

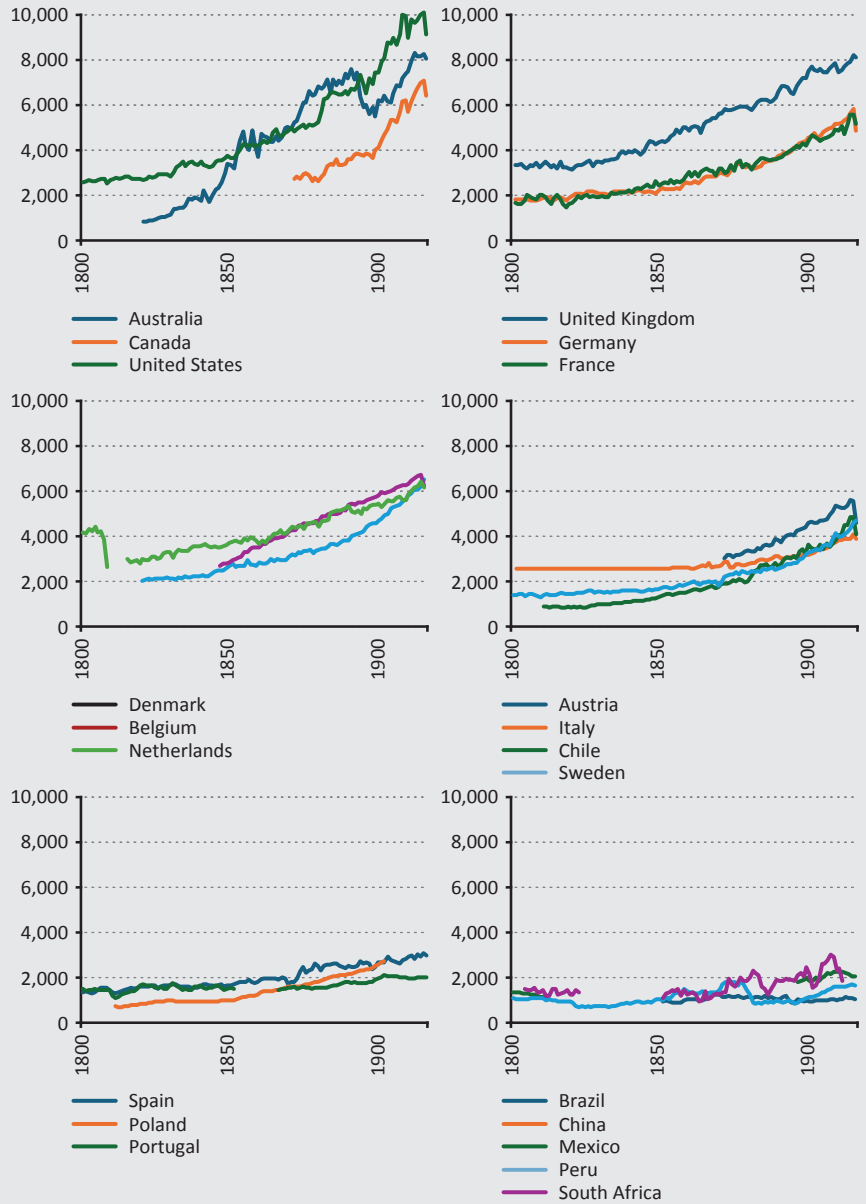
However, from the late 18th century onward, this long-standing pattern broke. Within a relatively short period, Europe moved from artisanal workshops to steam engines, mechanised factories, railways and unprecedented mass prosperity. This transformation, started in Britain, initially slowly but gradually accelerating towards the second half of the 19th century and eventually spread to other parts of Europe, including Germany, France, the Netherlands and Belgium, followed by a later and smaller wave in Italy, Sweden, Spain and Poland. Still, other parts of Europe (Portugal) and the world (China and Peru) remained in the low growth regime (*Figure 2*).

Joel Mokyr's work explains how this miracle happened. In fact, his work has reshaped our understanding of the origins and mechanisms of long-run economic growth by placing knowledge, institutions and cultural attitudes toward innovation at the centre of economic development (*Mokyr 1992, 2012*). His contributions offer a historically grounded explanation of how societies produce, organise and apply useful knowledge and translate ideas into sustained technological progress.

Mokyr's central argument is that the Industrial Revolution was not driven primarily by coal endowments or capital accumulation, nor was it merely a sequence of mechanical inventions or a response to relative factor prices. These conditions existed elsewhere without triggering sustained technological change. Rather, he argues, it was the consequence of a unique cultural and institutional transformation in Europe, which he calls the Industrial Enlightenment (*Mokyr 2012*).

The post-1700 period witnessed mechanisms for systematic accumulation of useful knowledge, including the establishment of institutionalised scientific societies, the codification of technical and scientific knowledge, norms of open scientific debate, improvements in communication, networking and dissemination, and a culture that valued problem-solving (*Mokyr 2012*). Artisans and scientists began to talk to one another. Inventors shared ideas in correspondence networks, coffee houses, philosophical societies and early scientific journals. Famous inventors – but also thousands of tinkerers, mechanics, instrument builders and autodidacts – perfected practical technologies in successive waves, transforming and creating whole industries. The belief that knowledge could improve society became widespread. This shift turned innovation into a cumulative, self-reinforcing process. In this view, societies prosper when they nurture openness, experimentation and freedom of thought (*Mokyr 2012*).

Figure 2
Evolution of per capita income from 1800 to 1914 (2011 PPP-adjusted USD)



Source: Maddison Project Database 2023 (https://www.rug.nl/ggdc/historicaldevelopment/maddison/releases/maddison-project-database-2023)

Indeed, Mokyr provides a micro-foundation for how innovation actually happens. His framework links three elements: (1) a formal understanding of natural laws; (2) practical techniques applying these natural laws and focused on how things can be made and improved in practice; and (3) a market and institutional environment that rewards experimentation (*Mokyr 1992, 2012*). This resonates strongly with the institutional perspective of *North* (*1990*) and the emphasis on social norms and self-governance in *Ostrom* (*1990*), both Nobel laureates. In other words, Europe's new emerging intellectual climate was focused on empiricism, openness to experimentation and a belief in useful knowledge, and it created an environment in which new ideas were systematically generated, tested, disseminated, applied, turned into products, commercialised and merchandised.

The Industrial Revolution, in Mokyr's view, emerged from a positive feedback loop between knowledge and incentives. New scientific understanding created opportunities for technological improvements, while a decentralised, competitive European political map encouraged inventors to seek patrons, apply their work commercially and migrate when constrained (*Mokyr 1992*). The lack of these interactions helps explain why earlier bursts of ingenuity did not translate into sustained growth. For example, the Hellenistic and Roman worlds produced sophisticated engineering inventions, but saw limited diffusion into broad-based productivity gains. Later episodes such as China's major advances (printing, metallurgy, navigation) or the Islamic Golden Age's scientific and mechanical achievements similarly failed to generate a self-sustaining industrial take-off.

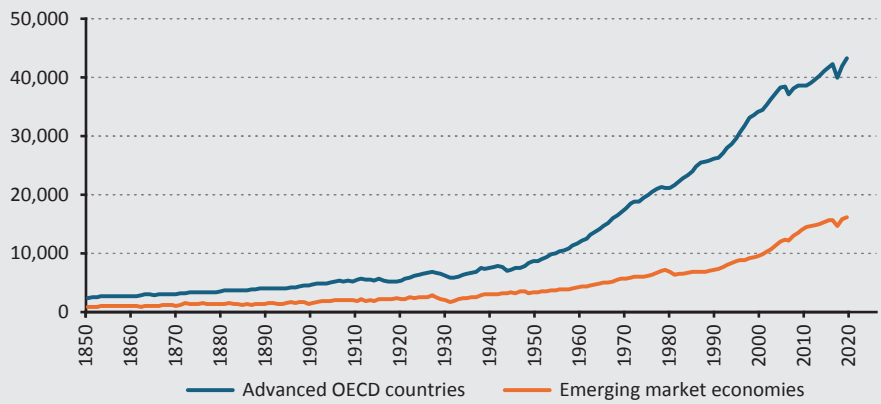
Mokyr also emphasises the supply side of ideas. Whereas endogenous growth theory (*Romer 1990*; *Aghion – Howitt 1992*) models innovation incentives and the macroeconomic consequences of R&D and market structure, Mokyr explains what shapes the production of ideas themselves: how societies cultivate skills, curiosity and intellectual openness (*Mokyr 1992, 2012*). His work thus complements the economics Nobel tradition by offering a historical-institutional explanation for why the West innovated first, why growth persisted and how knowledge regimes evolve. Overall, Mokyr's contribution shows that sustained economic growth is fundamentally a cultural and institutional achievement, rooted in the organisation of knowledge and the social attitudes that make innovation possible (*Royal Swedish Academy of Sciences 2025*).

5. Innovation, creative destruction and the post-World War II period

If Joel Mokyr explains how the modern engine of growth was ignited, Philippe Aghion and Peter Howitt explain how it continues to run. Motivated by the post-World War II growth experience, their framework helps make sense of the explosive and unprecedented acceleration of economic growth observed in leading OECD

countries. Those frontier advances then benefited many other countries indirectly, as new technologies diffused internationally and were adopted and adapted through trade, FDI and imitation. Post-war economic development far exceeded the development seen in the 19th and early 20th centuries. While per capita income levels doubled from 1800 to around 1900, they increased by a factor between 4 and 6 from 1950 to 2020 in Western countries (*Figure 3 and Figure 10 in the Appendix*).

Figure 3
GDP per capita, 1850–2022 (2011 PPP-adjusted USD)



Note: Advanced OECD countries is the average of Australia, Austria, Belgium, Canada, Germany, Denmark, Spain, France, the United Kingdom, the Netherlands, Poland, Portugal, Sweden and the United States. Emerging market economies is the average of Brazil, Chile, China, Mexico, Peru and South Africa.

Source: Maddison Project Database 2023 (https://www.rug.nl/ggdc/historicaldevelopment/maddison/releases/maddison-project-database-2023)

Aghion and Howitt's central idea is borrowed from Joseph Schumpeter. *Schumpeter* (*1911, 1942*) described capitalism as driven by "gales of creative destruction", in which new firms and technologies displace old ones, generating both progress and instability. When a new firm invents a better product, the old one loses value. When a new method of production appears, outdated factories are scrapped. Each innovation replaces older technologies, reallocates market shares and forces firms to exit. Creative destruction is not a side effect of growth but its beating heart. However, Schumpeter's account was largely descriptive and lacked a formal model specifying how frequently innovations occur, how large their quality improvements are, and how profits and R&D incentives interact.

Aghion and Howitt's seminal 1992 paper transforms Schumpeter's idea of creative destruction into a fully micro-founded theory of innovation-driven growth based on Schumpeterian creative destruction (*Aghion – Howitt 1992*). Their paper and the subsequent body of work provided what earlier Nobel laureates had not:

a rigorous framework in which long-run growth is driven by the incentives of firms to innovate, compete, enter and replace incumbents (*Aghion – Howitt 1997, 2008*). Their Schumpeterian model shows that growth results from a continual flow of innovations by entrants and incumbents, each seeking monopoly rents but constantly challenged by the next wave of innovators (*Royal Swedish Academy of Sciences 2025*).

They develop an endogenous growth model in which innovations arrive stochastically, raise productivity step by step through a quality-ladder mechanism and generate temporary monopoly profits until displaced by newer ideas (*Aghion – Howitt 1992*). Aghion – Howitt shares key foundations with the Romer tradition of endogenous growth: innovation is a profit-driven activity under imperfect competition, innovators earn market power rents and knowledge spillovers mean that private and social returns to R&D diverge. The crucial difference is the nature of technological progress. Romer-style models emphasise largely horizontal innovation and growth through expanding product varieties, whilst Aghion–Howitt emphasises vertical innovation, in which new ideas improve quality and productivity along ladders and typically replace older technologies, making creative destruction a central mechanism rather than a by-product.

In baseline Schumpeterian models, the private return on innovating scales with market size: a larger (or more integrated) market raises the rents from a successful innovation, which can increase equilibrium R&D effort and, under the baseline specification, the long-run growth rate. This scale effect parallels the market-size channel in *Romer* (*1990*).

By making firms' R&D choices depend on expected profits, competition, intellectual property protection and other policy variables, they show precisely when innovation incentives rise or fall, allowing clear analysis of how patents, taxes, subsidies and market structure affect long-run growth (*Aghion – Howitt 1997, 2008*). Their framework also distinguishes incremental from radical innovation, explains how distance to the technological frontier shapes growth strategies and models the strategic behaviour of incumbents and entrants (*Aghion et al. 2005b*; *Aghion – Howitt 2008*). Because the model is explicit, it links directly to data on patents, R&D, entry and exit, and productivity, providing testable predictions and a rigorous foundation for modern empirical research on innovation and growth (*Aghion et al. 2013*).

This framework has profound empirical and policy implications. First, their model helps answer the simple question: why do some economies grow faster than others, even with the same access to global technology? Their answer is because some economies allow new firms to enter, challenge incumbents and push the frontier

forward, while others protect old firms and stagnate (*Aghion – Howitt 2008*; *Aghion et al. 2005*b).

Second, they emphasise the crucial role of frontier innovation versus catch-up growth. In late-industrialising economies, growth arises from technology adoption and structural transformation; in frontier countries, growth depends on innovation intensity, education quality, venture capital, and the flexibility of labour and product markets. Thus, frontier economies are more sensitive to innovation-policy choices (*Aghion – Howitt 2008*; *Aghion 2009*; *Aghion et al. 2009*).

Third, Aghion and Howitt's research reveals that innovation is intensely microeconomic. It happens inside firms, in labs, design offices and startups, driven by people who want to "escape competition" by inventing something better. Too little competition makes firms lazy; too much makes innovation unprofitable. The sweet spot lies in the middle. In a follow-up work, *Aghion et al.* (*2015*) show this formally and highlights the central role of competition in innovation. They find that contrary to fears that competition discourages research, the relationship is inverse-U-shaped: too little competition protects incumbents, while too much erodes the rents needed to finance innovation. The optimal point stimulates firms to innovate in order to "escape competition" (*Aghion et al. 2005a*; *Aghion – Griffith 2005*).

Fourth, Aghion and Howitt provide a unified framework linking innovation, inequality, competition, taxation, education, financial development and industrial policy (*Aghion – Howitt 1997, 2008*; *Aghion et al. 2013*). Their research shows: i) how education and human-capital policies shape innovation capacity (*Aghion 2009*; *Aghion et al. 2009*), ii) how labour-market rigidities influence reallocation and innovation (*Aghion et al. 2009*; *Aghion – Howitt 2008*); iii) how trade and foreign direct investment accelerate creative destruction (*Aghion et al. 2005b*; *Aghion – Howitt 2008*); and iv) how carbon taxation and green innovation interact (directed technological change), demonstrating that appropriate combinations of carbon taxes and research subsidies can reorient innovation towards clean technologies without sacrificing long-run growth (*Acemoglu et al. 2012*).

Finally, their recent work examines industrial policy. Unlike the discredited picking winners approaches of mid-century, from a Schumpeterian perspective, a modern, competition-friendly industrial policy does not support incumbents but potential entrants in technologically dynamic sectors (*Aghion et al. 2015*). Their framework thus provides both macroeconomic justification and microeconomic guidance for modern innovation policy. This view offers a modern vision for industrial policy, not by subsidising old giants, but by supporting potential challengers in innovative sectors. They show that the state can help but must avoid suffocating the creative destruction that drives progress.

6. Innovation and employment

Aghion and Howitt's Schumpeterian growth framework links innovation to employment through creative destruction. New technologies and entrants expand some activities while displacing others. The key labour-market consequence is often reallocation. New jobs are created in new and expanding firms, whereas jobs are destroyed in shrinking and failing firms. Innovation can raise productivity, but it can also generate transitional unemployment and distributional costs (*Aghion – Howitt 1992*).

The long-run effect of faster growth and innovation on unemployment is ambiguous, because two forces pull in opposite directions. First, when technology improves faster, existing jobs become outdated sooner, raising separations and putting upward pressure on unemployment. At the same time, when the economy is growing faster, a new job or a new idea is likely to generate higher future profits, increasing the net present value of creating them. Firms are therefore more willing to hire and create new jobs, putting downward pressure on unemployment (*Aghion – Howitt 1994*).

Mokyr's long-term employment perspective relates to technological anxiety. Fears that new technologies will permanently destroy jobs recur throughout history, but past waves of mechanisation typically produced new tasks, new industries and new demand that absorbed labour over time. This process nonetheless imposed real short-run disruptions on particular occupations and regions (*Mokyr – Vickers – Ziebarth 2015*). Overall, the employment effects of innovation may depend crucially on institutions that facilitate reallocation (competition and labour market mobility) and adaptation (training policies).

Applied to Artificial Intelligence (AI) and employment, this same framework implies that outcomes depend on whether AI primarily accelerates task substitution (raising separations and churn) or also boosts entry, new activities and vacancy creation (raising job-finding). In other words, AI can increase measured job turnover and transitional unemployment if it speeds creative destruction faster than the economy's matching, training and reallocation mechanisms can absorb workers. But it can also reduce unemployment if it raises the profitability and pace of new firm creation and new job formation. Mokyr's technological anxiety perspective complements this by stressing that repeated historical waves of automation created severe displacement for some groups, but were often followed by new tasks and industries. The key question for AI is the *speed and inclusiveness of adjustment* (skills, diffusion, institutions), not a mechanical prediction of permanent mass unemployment.

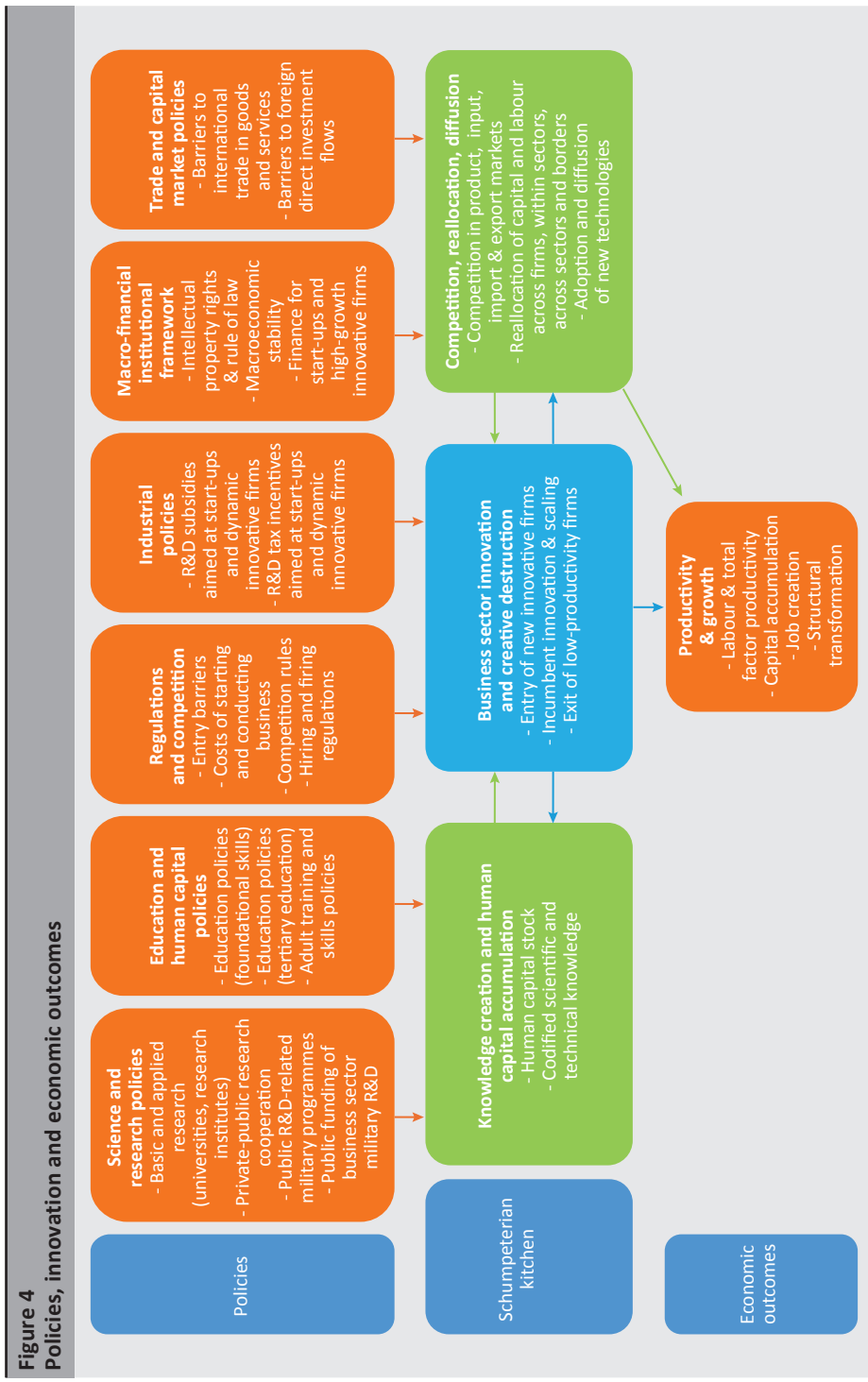
7. Public policies and innovation

Aghion and Howitt's work helps explain why innovation, productivity and economic growth accelerated from the late 19th century and continued to surge after World War II. They place innovation incentives and diffusion at the centre of a policy-sensitive growth process. In their Schumpeterian framework, sustained productivity growth depends not only on discoveries at the frontier, but also on the rate at which firms invest in R&D, adopt new technologies and reallocate resources toward more productive uses. This immediately brings public policy into the story: education and skills shape a country's ability to innovate and absorb technologies; openness to trade and foreign direct investment (FDI) expands access to ideas and financial development, affecting whether innovative projects, often risky and intangible, can be funded at scale.

Crucially, Aghion and Howitt link long-run growth to institutions and policies that frame entry, exit and competition, because creative destruction requires that new, more productive firms can enter and expand, while obsolete technologies and low-productivity firms shrink or exit. Competition policy, product-market regulation, bankruptcy regimes and administrative barriers to entry therefore influence how strongly innovation translates into aggregate productivity gains. Similarly, labour-market and social policies matter insofar as they shape mobility, reallocation and retraining, determining whether workers can move from declining activities into expanding innovative sectors. Intellectual property rights and innovation policies (patents, R&D tax incentives, subsidies) further affect the private returns on discovery, but also interact with diffusion and competition.

Seen this way, this section organises the main public-policy channels to show how the long-run institutional changes highlighted by Mokyr (scientific capability, incentives, and a supportive institutional environment) are complemented by Aghion–Howitt's emphasis on competition and reallocation. We now turn to a closer examination of these key factors, as sketched in *Figure 4*.

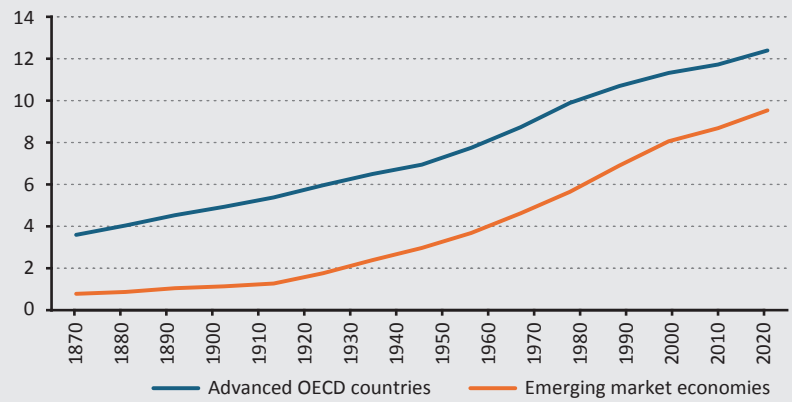
Figure 4
Policies, innovation and economic outcomes



7.1. The rollout and upscaling of public education and the rise of human capital

Human capital is a central driver of innovation, underpinning the creation of new ideas, their practical application and the diffusion of technologies across firms, sectors and borders. Since the 19th century, the stock of human capital has expanded through three major waves of educational development that fundamentally transformed the innovative capacity of advanced economies. The first wave, in the late 19th century, established universal primary education to promote basic literacy and numeracy skills for industrialising societies, pioneered by Prussia, in need of literate army officers, and followed by other European countries, with France and the United Kingdom introducing compulsory schooling in the 1880s. By 1900, up to 70 per cent of children in Western Europe and the United States were enrolled in primary education, albeit with uneven quality. The second wave, from the late 1940s to the 1970s, brought the mass expansion of secondary education, as school-leaving ages were raised and lower secondary schooling became the norm. The third wave, from the 1970s onwards, saw the massification of tertiary education, transforming higher education from an elite system into a majority experience for younger cohorts in many OECD countries (*Figure 5*).

Figure 5
Mean years of schooling, 1870–2020



Note: Advanced OECD countries is the average of Australia, Austria, Belgium, Canada, Germany, Denmark, Spain, France, the United Kingdom, the Netherlands, Poland, Portugal, Sweden and the United States. Emerging market economies is the average of Brazil, Chile, China, Mexico, Peru and South Africa.

Source: Leandro Prados de la Escosura (2021) – with minor processing by Our World in Data. "Average years of schooling" [dataset]. Leandro Prados de la Escosura, "Augmented Human Development Index (AHDI) – Country data"; Leandro Prados de la Escosura, "Augmented Human Development Index (AHDI) – Regional data" [original data]. Retrieved 9 December 2025 from https://archive.ourworldindata.org/20251209-133038/grapher/years-of-schooling-prados-de-la-escosura.html (archived on 9 December 2025).

These successive expansions had profound innovation consequences: primary education enabled early industrialisation and the diffusion of mechanical technologies; secondary education supported the post-war productivity boom by providing skills for increasingly complex production; and tertiary education strengthened national innovation systems by expanding the supply of scientists and engineers, reinforcing universities as hubs of research and science-industry linkages,

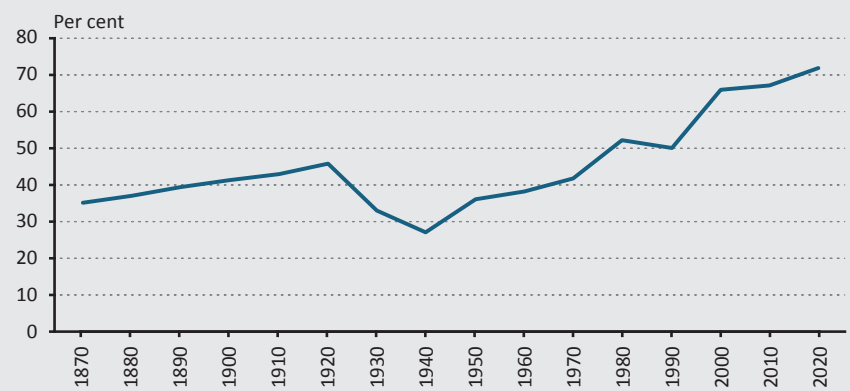
and fostering R&D, knowledge spillovers and the development of general-purpose technologies such as ICT, biotechnology and, more recently, artificial intelligence.

7.2. Trade integration, capital flows and technological diffusion

Since the early 19th century, international trade and capital flows among industrialised countries have expanded in successive waves, with temporary reversals but a clear long-run trend towards deeper integration. From 1870 to 1914, falling transport and communication costs (railways, steamships, telegraph) and relatively liberal trade policies led to a sharp rise in trade among industrial economies, supporting specialisation and economies of scale in manufacturing. Trade and capital flows resumed after 1945. From the 1990s onwards, the creation of the WTO, falling ICT and transport costs, and the rise of global value chains pushed trade openness to historically unprecedented levels. Since the global financial crisis, trade integration has slowed and come under political pressure, but it remains far higher than at any time before the late 20th century (*Figure 6*).

The long-run integration of trade and capital markets strongly supported technological diffusion and returns on innovation. Open trade expanded market size, allowing firms to exploit increasing returns on scale and spread fixed R&D costs over much larger sales volumes. Trade in capital goods and intermediate inputs became a key channel for the international transmission of new technologies. Foreign direct investment further accelerated diffusion by transferring not only capital but also managerial practices, organisational know-how and proprietary technologies. International openness also reinforced specialisation in high-productivity, innovation-intensive sectors and strengthened incentives to invest in R&D. This process has accelerated technological diffusion and increased both private and social returns on innovation in the industrialised world.

Figure 6
Trade openness in the OECD average: Export and imports over GDP, 1870–2020

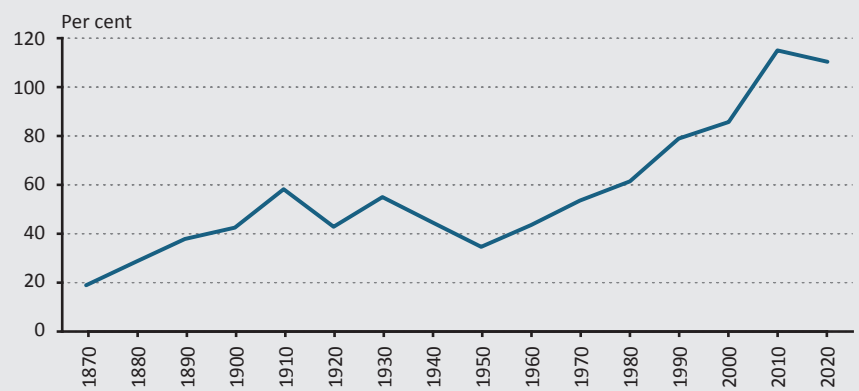


Note: Average of Australia, Belgium Canada, Switzerland, Germany, Denmark, Spain, Finland, France, the United Kingdom, Ireland, Italy, Japan, the Netherlands, Norway, Portugal, Sweden and the United States.
Source: Jordà-Schularick-Taylor Macrohistory Database (https://www.macrohistory.net/database/)

7.3. Financial system development

Financial system development is central to expanding firms' access to external funding and thereby supporting innovation. Since the early 19th century, financial systems in industrialised economies have evolved from small, local banking networks into large, diversified systems combining powerful banks (*Figure 7*), deep capital markets, and more recently, specialised venture-capital and private-equity finance. Early advances in joint-stock banking, central banking and bond markets helped finance industrialisation and large infrastructure projects, while the tightly regulated, bank-dominated post-war system provided stability but limited risk-taking. From the late 1970s onwards, financial liberalisation, global integration and technological change spurred the rapid expansion of equity and bond markets, the rise of institutional investors and the emergence of venture capital as a key mechanism for funding high-risk, technology-intensive innovation. By relaxing financing constraints, well-developed financial systems, banks and markets alike, enable firms to undertake long-term, intangible-intensive investments and pursue high-risk, high-reward experimentation.[3]

Figure 7
Credit-to-GDP ratios in the OECD average, 1870–2020



Source: Jordà-Schularick-Taylor Macrohistory Database (JST) (https://www.macrohistory.net/database/)

7.4. Intellectual property rights

Since the early 19th century, intellectual property rights (IPR) in today's OECD countries have evolved from patchy, nationally limited protections into broadly harmonised, enforceable systems designed to secure returns on innovation as part of a wider strengthening of institutions. Early patent and copyright laws existed in

[3] At the same time, the experience of financial crises has shown that when financial development is accompanied by inadequate regulation, instability can disrupt credit provision, damage firm balance sheets and undermine innovation. This underscores that innovative activity thrives most when financial systems are both well-developed and well-regulated.

Britain, France and the US in the 18th–19th centuries, but coverage was narrow, enforcement uneven and international protection weak. In the late 19th and early 20th centuries, multilateral treaties such as the Paris Convention (patents, 1883) and the Berne Convention (copyright, 1886) began to create minimum common standards and the principle of national treatment, so inventors and authors enjoyed similar protections abroad as at home. After 1945, and especially from the 1960s onwards, most OECD countries progressively modernised their patent, copyright and trademark regimes, clarifying subject matter, procedures and durations, and building more professional patent offices and specialised courts, which improved legal certainty and reduced transaction costs for innovators.

From the 1980s and 1990s, IPR protection deepened and globalised further: the creation of the WTO's TRIPS Agreement[4] (1994) set binding minimum standards for patents, trademarks and copyright for member countries, and many OECD members also strengthened protection for pharmaceuticals, software, semiconductors and other knowledge-intensive sectors, while expanding the role of trademarks, designs and (later) data and digital rights. At the same time, competition policy, contract enforcement, corporate governance and regulatory quality improved in most OECD economies, creating a broader institutional environment in which innovators could expect contracts to be enforced, piracy to be sanctioned and disputes to be resolved in a predictable way.

However, the desirability of strong patent protection remains contested. While patents can strengthen innovation incentives by allowing inventors to appropriate returns, they also create monopoly power and can slow diffusion or raise barriers for cumulative, follow-on innovation. A prominent critique argues that many innovation episodes have occurred with weaker intellectual monopoly rights and that strong IPR can, in some settings, do more harm than good (*Boldrin – Levine 2008*). More generally, formal endogenous growth and trade frameworks treat IPR as a policy trade-off between dynamic innovation incentives and static efficiency and diffusion (*Grossman – Helpman 1993*).

7.5. The Cold War's arms and space race

During the Cold War, the arms race and the space race turned scientific and technological superiority into a core element of geopolitical competition, leading to massive public investment in both basic and applied research, especially in the United States and the Soviet Union. US-led military and space research generated general-purpose technologies that diffused internationally and became foundational infrastructures of the modern digital economy.

[4] The TRIPS Agreement (Agreement on Trade-Related Aspects of Intellectual Property Rights) is one of the most important agreements of the World Trade Organization (WTO), which regulates the trade-related aspects of intellectual property rights at a global level. It entered into force in 1995 as a result of the Uruguay Round, and its aim is to achieve international harmonisation of intellectual property protection.

Defence and space agencies funded fundamental work in physics, mathematics, electronics, materials science and computer science, while also driving highly mission-oriented applied R&D in rocketry, guidance systems, satellites, sensors, computing and secure communications. In this process, the United States emerged as the world's central innovation powerhouse and technological hub, combining large defence budgets, world-class universities, federal research agencies and dynamic private firms. This US-centred innovation system generated major civilian spillovers with global diffusion to other advanced economies. The internet grew out of the defence-funded ARPANET[5] project; GPS was developed as a military satellite navigation system before spreading to civilian use; and rapid advances in computation and microelectronics were driven by nuclear weapons, missile guidance and space exploration, with programmes such as Apollo accelerating the development and cost reduction of integrated circuits. For the most recent period, new empirical evidence indicates that defence-related public R&D significantly increases private business R&D and leads to substantial productivity gains in downstream industries, with cross-country spillovers through international technology diffusion (*Moretti et al. 2025*).

7.6. Competition policies and sectoral regulation

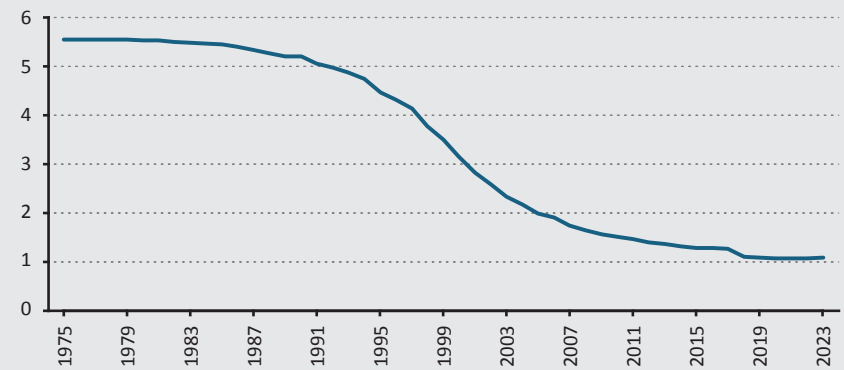
Relatively recent developments in competition and labour/product market policies, innovation-oriented tax instruments and digitalisation strategies have raised both the incentives and the capabilities for firms to innovate. Where these three areas are well-aligned (strong competitive pressure and reallocation, well-targeted R&D tax support, and broad-based digital adoption) OECD evidence tends to find stronger innovation, faster diffusion and higher productivity growth; where one or more are weak, productivity gains from new technologies are more muted.

First, competition, product and labour market policies have generally moved (with differences across countries and over time) towards more pro-competition, pro-entry frameworks since the 1980s: product market deregulation, the liberalisation of network industries and stronger competition enforcement have lowered barriers to entry and exit and reduced state control in many sectors, while labour market reforms have sought to combine basic protections with more flexible hiring and reallocation. The USA and other Anglo-Saxon countries were leading the way in creating more competition-friendly business environments. For instance, the US started deregulating and liberalising its network sectors, especially the telecoms in the early 1980s already, whereas Europe followed suit with a delay of decades (*Figure 8*).

[5] ARPANET (Advanced Research Projects Agency Network) was a pioneering computer network developed by the U.S. Department of Defense in the late 1960s and is the direct predecessor to today's Internet. It was the first network to successfully use packet-switched data transmission, allowing computers at remote research institutes and universities to be connected from 1969 onwards.

These reforms tend to boost innovation and productivity by increasing the threat of entry, speeding the reallocation of labour and capital away from low-productivity incumbents, and allowing high-productivity, often younger, more innovative firms to grow faster. The recent policy debate is about how to sustain that dynamism in the face of rising market concentration and superstar firms in some digital and globalised industries.

Figure 8
Product market regulation in the OECD average, 1975–2023: Evolution of the Energy, Transport and Communications Regulation (ETCR) indicator



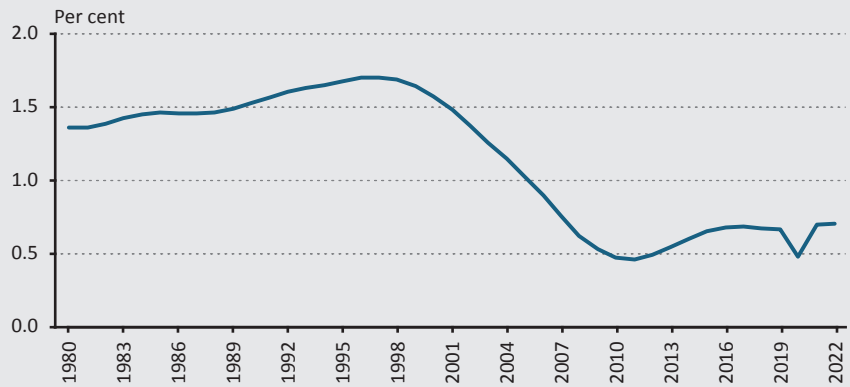
Note: Scale of 0 to 6 (0 = least regulated, 6 = most regulated)

Source: Calculations based on OECD. OECD ETCR indicators (https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwinqevukfCSAxVwU6QEHVrHCIYQFnoECB0QAQ&url=https%3A%2F%2Fwww.oecd.org%2Fcontent%2Fdam%2Foecd%2Fen%2Ftopics%2Fpolicy-sub-issues%2Fproduct-market-regulation%2FETCR%2520indicator%2520values.xlsx&usg=AOvVaw1J_tPcjCIvAne5F5S9W744&opi=89978449)

8. The post-2005 productivity slowdown

The staggering productivity gains and economic growth in the thirty years after World War II started slowing down in the 1990s and the growth engine started really stuttering in the post-2005 period. A marked, persistent decline in labour-productivity and total-factor-productivity growth has occurred across most advanced economies since the mid-2000s. The slowdown is broad-based, affecting the United States, the euro area, the United Kingdom, Japan and most other OECD economies, and is visible across many sectors rather than being confined to a few specific industries. In terms of magnitude, typical productivity growth rates in advanced economies fell from around 2–3 per cent per year in the late 1990s and early 2000s to around 1 per cent or less after the mid-2000s. *Figure 9* illustrates the marked slowdown in productivity growth from the mid-2000s onwards relative to earlier periods.

Figure 9
Productivity growth slowdown, OECD average



Note: Average TFP growth calculated for 17 OECD countries with full data coverage from 1980 to 2022.
Source: Calculations based on TFP data drawn from OECD (2023).

8.1. The Gordon vs. Mokyr debate: Innovation on the brink of a permanent decline?

The Gordon vs. Mokyr debate, which was so loud in academia a few years ago, was about whether there is a permanent slowdown in innovations. Robert Gordon represents the pessimistic view that most important technological breakthroughs have already happened (*Gordon 2012, 2016*). He points to electricity, the internal combustion engine, sanitation and mass production as unique, once-in-a-century innovations that transformed living standards and productivity. According to Gordon, recent innovations such as smartphones, social media, and even much of information technology mostly improve comfort and entertainment rather than fundamentally raising productivity. He also emphasises structural headwinds, such as aging populations, rising inequality, high debt and slowing educational progress. As a result, he predicts that advanced economies will experience permanently lower productivity growth in the long run.

Joel Mokyr strongly disagrees with this pessimistic view. He argues that innovation is not slowing down, but rather changing form. According to Mokyr, we are entering a new era of scientific and technological progress driven by artificial intelligence, biotechnology, materials science, neuroscience and other advanced fields. He emphasises that modern innovation is combinatorial, meaning that new ideas are created by recombining existing knowledge at an accelerating pace. He also stresses that major technologies often take a long time to show their full productivity impact, just as electricity and computers did in the past (*Mokyr 2017, 2018*). From this perspective, today's weak productivity growth does not mean that innovation has stalled. Instead, it may simply reflect slow diffusion. Mokyr therefore believes that long-run technological progress will continue.

More generally, Mokyr's line of thoughts illuminates contemporary growth challenges. Mokyr argues that societies stagnate when they become hostile to disruptive ideas, when vested interests gain power, or when ideology turns against openness, echoing the modern concerns of *Acemoglu – Robinson* (*2012*) about extractive institutions. His logic provides a framework for analysing the post-2005 productivity slowdown, where declining business dynamism, slower diffusion of frontier knowledge, risk aversion and regulatory rigidity may be constraining modern innovation systems (*Mokyr 2017, 2018*). Mokyr reminds us that innovation thrives in environments that reward creativity and welcome new ideas. Societies that fear change or protect incumbents risk stagnation.

8.2. Creative destruction and the productivity slowdown

Aghion's and Howitt's interpretation of innovation driven by creative destruction provides a bridge between these two opposing views (*Aghion – Howitt 1992, 2008*). Accordingly, economic growth depends not only on technology itself, but also on the incentives and institutions that shape innovation. Key factors include competition, access to finance, education, property rights and openness to new firms. Aghion emphasises the role of creative destruction, where new innovators replace old incumbents. If markets are competitive and entry barriers are low, innovation leads to strong productivity growth, supporting Mokyr's optimistic view. If incumbents block competition, investment is weak and inequality rises, innovation may fail to translate into growth, leading to outcomes closer to Gordon's pessimistic scenario. In this sense, growth is not technologically predetermined but depends on policy and institutional design.

More generally, Aghion and Howitt's Schumpeterian framework suggests why productivity growth might have slowed in advanced economies since the mid-2000s. It is not necessarily because we have run out of ideas. In their quality-ladder model, aggregate TFP growth is driven by the pace of creative destruction – the rate at which new technologies and entrants replace old ones, which depends on expected innovation rents, competition, and the ease of entry and reallocation (*Aghion – Howitt 1992, 1994, 2008; Aghion et al. 2013*). Growth can therefore slow when business dynamism weakens and diffusion slows, even if frontier science and invention remain active. This interpretation also resonates with Mokyr's emphasis on diffusion lags and institutional headwinds (*Mokyr 2017, 2018*).

The empirical literature indeed documents a decline in business dynamism, measured by firm entry and exit, job reallocation and the contribution of young firms to employment growth, in the United States and in other OECD economies. Using US Census microdata, *Decker et al.* (*2014, 2016, 2020*) and *Cooper et al.* (*2024*) show that start-up rates, job reallocation and the share of high-growth young firms have fallen sharply since 2000, contributing to weaker allocative efficiency and slower productivity growth. Parallel evidence shows that similar declines in

entry rates and young-firm employment shares have occurred across many OECD countries, especially after the Global Financial Crisis (*OECD 2017*; *OECD 2019*). OECD work further shows that while productivity growth at the global technological frontier has remained relatively robust, productivity diffusion to laggard firms has slowed markedly, pointing to falling business dynamism and rising barriers to reallocation, rather than a collapse of frontier innovation as key drivers of the post-2005 productivity slowdown (*Andrews et al. 2016*; *OECD 2019*).[6]

A related literature links declining dynamism to rising market concentration and increased mark-ups (*De Loecker et al. 2020*) and tighter financial conditions for young firms that impede entry and exit (*Philippon 2019*; *OECD 2015*; *Aghion et al. 2019*); weakened competitive pressures and higher reallocation frictions now weigh on both productivity growth and innovation across much of the OECD.

Many of the forces that previously boosted innovation and productivity have slowed since the mid-2000s, turning from tailwinds into headwinds. In particular, the strong post-war expansion in education has lost momentum across many advanced economies. The slowdown in the growth of average years of schooling, combined with enduring gaps in basic skills for sizable segments of the population, has reduced the growth of effective labour input (*Goldin et al. 2024*; *Moss et al. 2020*). Slower human-capital accumulation not only directly limits productivity growth, but also constrains the adoption, diffusion and efficient use of new, skill-intensive technologies, especially those based on ICT, data and artificial intelligence. In this way, human-capital weakness acts less as an independent drag and more as a multiplier of broader diffusion failures, weak innovation returns and sluggish reallocation. As a result, a non-trivial share of the post-2005 productivity slowdown likely reflects an increasing misalignment between the rapidly rising skill requirements of new technologies and the more modest expansion of advanced and intermediate skills in the workforce (*Andrews et al. 2024*).

At the same time, the momentum of pro-competitive regulatory reforms has faded or in some cases partially reversed, potentially lowering competitive pressure and productivity growth (*Syverson 2011*). For instance, the slowdown in network-sector deregulation alone can account for up to one-sixth of the post-2005 productivity slowdown (*Andrews et al. 2025*). Finally, as globalisation has lost momentum since the mid-2000s, the forces of trade-induced competition, technology transfer and

[6] Digitalisation policy has become a central plank of innovation and productivity strategies. Since the 1990s, and especially since the mid-2000s, OECD governments have invested in broadband infrastructure, spectrum policy and telecoms competition, and then more recently in AI, cloud, data governance and cybersecurity. These efforts have enabled frontier firms to use digital tools (cloud, big data, AI, platforms) to raise productivity, create new business models and scale innovations globally, but diffusion to laggard firms remains incomplete, contributing to widening productivity gaps within countries.

participation in global knowledge networks that once boosted productivity have visibly weakened (*Goldin et al. 2024*).[7]

Since the mid-2000s productivity slowdown in many OECD economies, governments have increasingly leaned on R&D tax incentives to stimulate business innovation and revive productivity growth. Over the past two decades, these incentives have spread and become more generous across the OECD. Many countries have also adopted IP (patent) boxes, that is preferentially low tax rates on income earned from patents and other intellectual property, to boost after-tax returns from successful innovation. While R&D tax incentives might increase business R&D on average, they are not always well targeted and often disproportionately benefit large incumbents rather than high-growth entrants.

9. Conclusion: Public policies to revive the growth engine?

Aghion and Howitt's Schumpeterian theory is ultimately an optimistic one: it implies that growth can be reignited if policymakers succeed in restoring the conditions under which new ideas, firms and technologies can emerge and displace the old ones. Central to this is vigorous competition and low barriers to entry, which force incumbents to innovate and allow challengers to scale. It also requires open product and capital markets, so that ideas, technologies and managerial know-how can diffuse rapidly across borders. Flexible labour market institutions are essential to enable the swift reallocation of skills toward expanding, innovative firms, while well-functioning financial systems, including venture capital and risk finance, are needed to fund high-risk, high-potential projects. Finally, the state plays a critical enabling role: not by shielding declining incumbents, but rather by investing in basic research, human capital and innovation infrastructure, and by setting stable, pro-competitive rules that reward experimentation and tolerate failure. In this framework, sustained growth is not the product of protection or subsidy of the old, but of policies that continually renew the process of creative destruction.

[7] Measurement issues have also been examined as a potential explanation for the productivity slowdown. Rapid digitalisation, the growth of free digital services and quality improvements in ICT goods may not be fully captured in national accounts. However, the dominant conclusion in the literature is that mismeasurement can explain only a small fraction of the observed slowdown and cannot account for its timing, cross-country pervasiveness or persistence (*Syverson 2017*).

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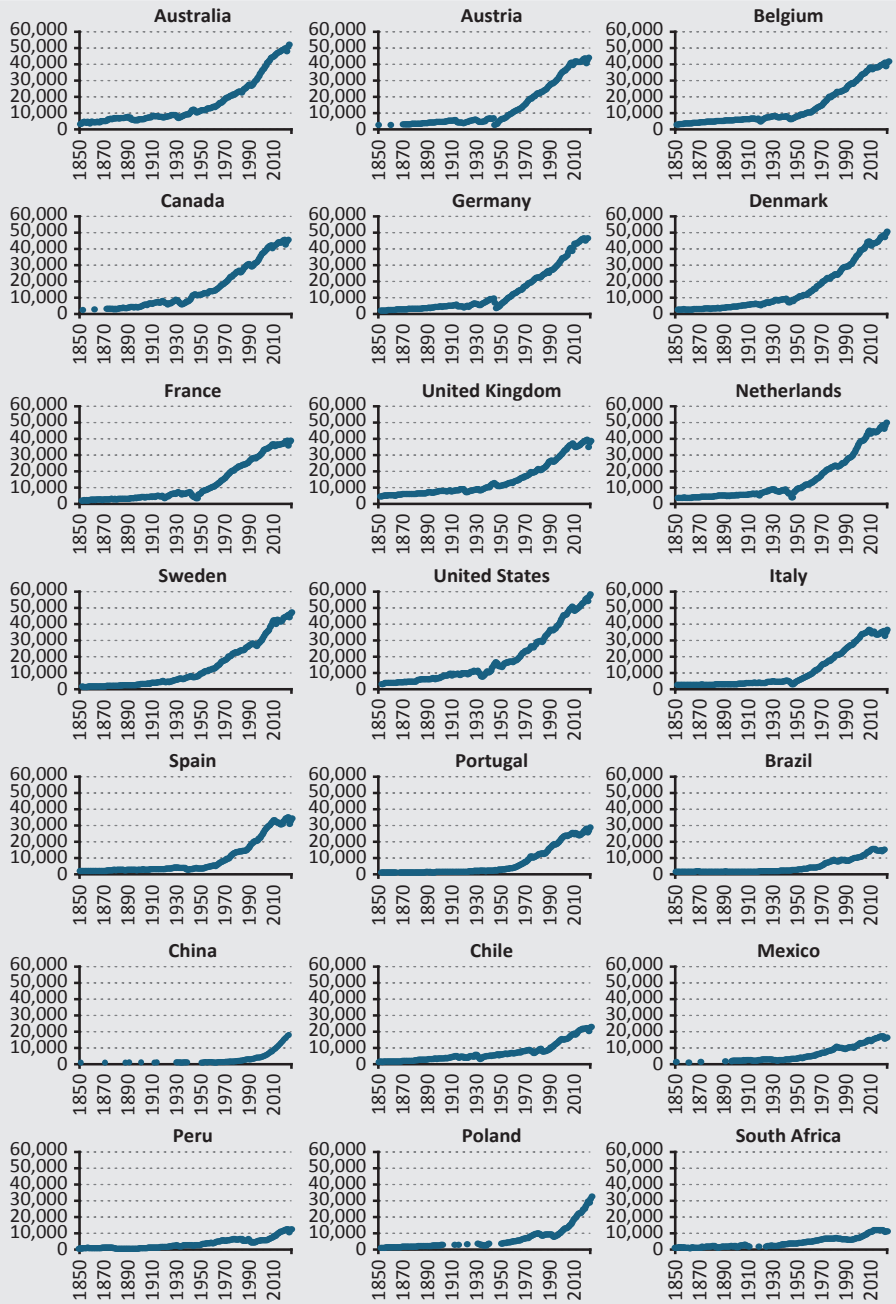
Appendix: Country-specific per capita income levels, 1850–2022

Figure 10
GDP per capita, 1850–2022 (2011 PPP-adjusted USD)



Source: Maddison Project Database 2023 (https://www.rug.nl/ggdc/historicaldevelopment/maddison/releases/maddison-project-database-2023)

The Role of Government Amidst Global Challenges*

Gábor P. Kiss – Katalin Szőke – Dóra Novák

The global trends emerging in the 21st century pose new challenges for economies and societies. In addition to individual involvement, many of these challenges require public policy and fiscal action, due to their complexity or scope. The most significant challenges, which have universal impact at the global level and are the subject of our study, are ageing, climate change, the digital revolution, the increasing importance of security policy, growing economic inequality, the rising burdens of public debt and the impact of globalisation on tax revenues. In this essay, we examine the impact of these simultaneous, large-scale trends, which increase budgetary expenditure and reduce revenue, on government budgets.

Journal of Economic Literature (JEL) codes: E62, H63, H70

Keywords: government, budget, ageing, climate change, digital revolution, security policy, inequality, public debt

1. Historical overview

The current role of government and the government budget in the economy, which varies from country to country but is significant overall, is a relatively new phenomenon in historical terms. Looking back over the long term, the government's weight in the economy has been growing steadily. This trend was most significant in the first three quarters of the 20th century, and has been more volatile since then (*Figure 1*).

Until the end of the 19th century, governments intervened only modestly in the economy. Although the history of taxation is as old as civilisation itself, its level was moderate for centuries, even millennia, compared to today's conditions. At the turn of the 19th and 20th centuries, government revenues typically remained below

* 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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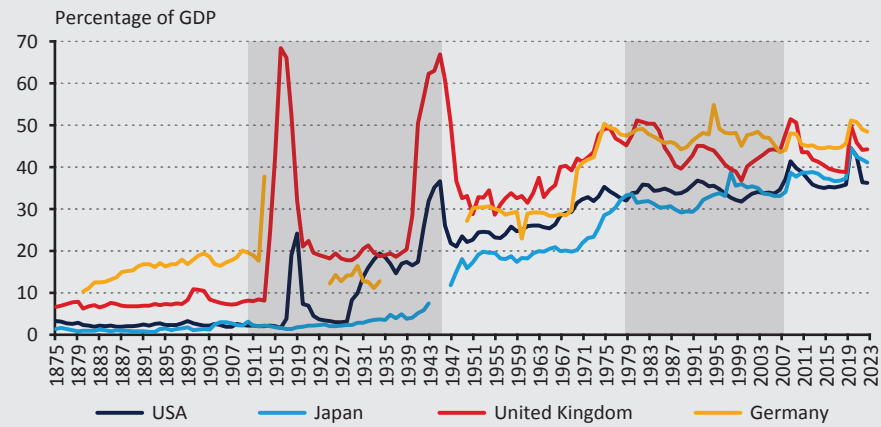
10 per cent of gross national product, which primarily covered the maintenance of basic government functions (national defence, public safety, public administration), while the role of redistribution was virtually non-existent.

However, there was a gradual increase in demand for the government to play a welfare role. For centuries, this was carried out in the form of social self-organisation (e.g. mutual benefit societies), but only sporadically and within a narrow circle. Growing demand and the expansion of suffrage from the end of the 19th century gradually led to the creation of new government institutions, such as pension and health insurance systems.[1] This increased the expenditure-to-GDP ratio, prompting corresponding budgetary adjustments, including increases in tax revenues.

Figure 1
Government expenditure as a percentage of GDP (1875–2023)



Source: IMF

From the early 1900s, but mainly during World War I and after the global economic crisis of 1929–1933, public expenditure rose steadily; therefore, government revenues also had to be gradually increased to cover it. The expenditure side was also increased by defence costs and the compensation costs of indirect effects incurred as a result of the war, as well as by public procurement and investments. The Keynesian economic model emerged, in which the budget was intended to play a role in stabilising economic cycles. Consolidation of the welfare state in Western societies after World War II is closely linked to the expansion of social rights, i.e. that everyone should be given the opportunity to enjoy a certain minimum level of economic welfare and security. As a result, although it had already appeared in

[1] Due to the retirement age exceeding the lower life expectancy at birth at the time, this expenditure did not place a significant burden on the budget.

some countries decades earlier, social security replaced mutual benefit societies on a wider scale, thereby increasing welfare spending, which in many countries raised the rate of government redistribution to over 50 per cent of GDP.

From the 1970s to 2010, as economic openness increased, the neoliberal approach sought to reduce the economic role of the government. The prefix "neo" indicated that the intention was not to return to *laissez-faire* economic thinking but rather to accept the role of the government in the modern economy, while conceiving of its role within strict frameworks and rules so as not to jeopardise the functioning of the market. As a result, government activism declined, the outsourcing of some of the tasks taken over by the government began, privatisation processes started and the dismantling of government regulation began – for example, the deregulation of freight transport, air transport and the financial system. In the former socialist region of Central and Eastern Europe, the wave of privatisation and deregulation began with the change of regime, later than in Western countries. The idea of a limited government, which was still dominant in the 1990s, was called into question in the 2010s (*Győrffy 2025*).

The role of government strengthened again in the 2010s and even more so in the early 2020s, driven first by the 2008 financial crisis and later by the series of widespread crises in the 2020s. The role of government becomes more important during financial and war crises, health emergencies and natural disasters. As a result, there is a growing demand for the regulatory function of the government, and fiscal expenditures and public debt increase. In the wake of the financial crisis, banking regulations were reviewed, and economic and industrial development came to the fore. During the Covid pandemic, individual governments significantly increased support for households and firms to help them weather the economic recession caused by lockdowns. Subsequently, in order to mitigate the effects of the global inflationary shock, many countries increased the number of various forms of government intervention (price controls, tax reductions, providing subsidies). As economic influence has grown, so has the regulatory framework through which government fulfils its economic role. It is important to find the right balance in regulating the economic system (*Nagy 2022*). This is because regulation has economic costs similar to those of taxation.

Therefore, overall, responses to significant social and economic challenges have determined the development of government budgets over the past 100–150 years, and we can continue to expect this to be the case. It is necessary to strengthen global coordination between governments, as problem areas have emerged (financial markets, environmental protection, energy policy, clean water, etc.) that governments are no longer able to remedy on their own (*Kálmán 2013*). *Elekes* (*2018*) used the three biggest global risks of the past decade (financial and fiscal risks, long-term unemployment and oil shock) and their potential impacts to show

when government intervention is absolutely necessary to avoid further negative effects. These examples also highlighted that the role of government is changing. A number of fundamental factors, geopolitical contexts and the need to address commitments related to pandemics or climate change may lead to policies that require the reorganisation of value chains. Economic policies should focus on increasing productivity and competitiveness (*Halmai 2023*).

2. Global challenges

The 21st century is characterised by the interconnection of inherited and newer global problems and ongoing transformations, while demographic, political, economic, technological and regional or global changes within governmental frameworks are unfolding at different speeds across societies (*Simai 2018*).

In the following, we examine how global challenges that affect all countries in the same way (typically negatively) will impact budgets in the future.[2] Attempts have been made to conduct a consolidated analysis and a detailed examination of the debt and expenditure-revenue structure (see, for example, the Office for Budget Responsibility (OBR)), but even these emphasise (*OBR 2018*) that there is a trade-off between comprehensiveness and certainty. Their method is criticised in seven points by *Baksay* and *P. Kiss* (*2023*). One of their findings is that it is not justified to assume that the accumulation of fixed assets will remain unchanged as a proportion of GDP, as it may decrease significantly in the long term if GDP-proportionate stocks converge with development or if they are independent of it, in which case their size will be determined by population trends (*Fanelli 2018*). In our essay, we do not attempt to apply the appropriately corrected methodology of the *OBR* (*2018*); therefore, we discuss the processes of global challenges separately. Since the beginning of the 21st century, there has been an increase in the number of studies and analyses presenting global medium- and long-term changes and the related risks. Among these, the report entitled *Global Trends*, published every four to five years by the Washington-based National Intelligence Council, and the *Global Risks Report*, published ahead of the annual meetings of the World Economic Forum in Davos, stand out. *János Matus*'s (*2019*) study provides a 2-part overview of the ideas and arguments published in the above sources over the past two decades and attempts to place the trends described in the context of international relations theory.

[2] Resource management and geopolitical transformations have different effects on different countries, with varying outcomes. Some will be winners and others losers as a result of these changes. This leads to conflicts, which we will return to in the section on defence and security policy.

2.1. Ageing

Looking at the world as a whole, there is a strong determination that the elderly population is growing both in terms of numbers and proportion, even though there are countries that are currently still in the phase of a population explosion. The proportion of persons aged 65 and over has almost doubled in the last half-century, rising from 5.5 per cent to 10.3 per cent. According to UN population projections, this figure will double again in the next half-century, reaching 20.7 per cent. Demographic trends vary significantly across different regions of the world. Currently, the proportion of persons aged 65 and over is highest in Europe and North America (19 per cent in 2022), which, according to *UN* (*2022*) calculations, could rise to 27 per cent by the middle of the century. By 2050, one in four people in East and Southeast Asia, as well as Australia and New Zealand, may be over 65. Meanwhile, Africa is still in the phase of a population explosion. The population of sub-Saharan Africa will nearly double by 2050. Taking into account changes in life expectancy at birth, the population could reach 2.1 billion. This region has the lowest proportion of elderly inhabitants: In 2024, it was only 3 per cent, and according to the *UN (2024)* forecast, it could be around 5 per cent in 2054 and only rise to 12 per cent by 2100.

An ageing society is therefore primarily characteristic of developed countries, but in the near future, it will pose a challenge for more and more developing countries, including China. Demographic changes have significant economic consequences: they transform the labour market, influence labour productivity, change consumption and savings habits, reshape the structure of production and also affect long-term growth prospects. Ageing puts pressure on government budgets: under current pension and social security rules, public expenditure increases significantly, while revenues decline as a result of shrinking labour supply. According to calculations by the *European Commission* (*2024*), the cost of ageing in the EU, which consists of pension, health, education and long-term care expenditures, accounted for 24.4 per cent of GDP in 2022 and could rise to 25.6 per cent by 2070. However, there is wide variation among EU Member States, with these expenditures in Ireland amounting to only 12 per cent of GDP in 2022, compared to 30 per cent and 27 per cent of GDP in France and Italy, respectively. Healthcare spending is being driven up not only by ageing populations but also by the spread of more expensive medical technology and the fact that higher life expectancy at birth is increasing the period during which people live with chronic diseases, which requires significantly more healthcare spending. In addition, as the dependency ratio increases, it will become increasingly difficult to keep pace with rising costs, as these are funded by contributions from a shrinking working-age population.

Examining data from the United States, *Braun et al.* (*2016*) found that the risk of poverty also increases with age. Pension systems around the world vary greatly in terms of welfare; some consider it the government's responsibility to provide a certain level of care for the elderly (e.g. in a pay-as-you-go pension system), while others encourage self-care, but the lack of government intervention may increase the risk of poverty in old age (*Ebbinghaus 2021*).

The IMF study (*IMF 2025*) examines the rise of the "silver economy", focusing on three key areas: the extent of healthy old age and its impact on labour markets, the broader economic implications of demographic changes, and the role of targeted measures to mitigate the negative effects of ageing on the economy. In many countries, people are not only living longer, but they are also in better health, which translates into longer and more productive working time. Alongside longer life expectancy, the functional capacity of older people has also improved over time. Newer cohorts of older people are physically stronger and have better cognitive abilities than previous cohorts of the same age. Healthy ageing will partially offset the impact of negative demographic trends, but global economic output growth will slow significantly in the 21st century, and many countries will need to make serious efforts to stabilise their GDP-to-public debt ratios. The continued growth in labour supply and the improvement in the human capital of older people due to healthy ageing are expected to contribute about 0.4 percentage point per year to global GDP growth between 2025 and 2050. In a period of global population ageing, a comprehensive policy approach can increase labour supply, boost growth and ease fiscal pressures. The impact of population ageing on growth can be significantly offset by lifelong policies such as supporting the human capital of people between the ages of 50 and retirement age, including health promotion and preventive measures.

2.2. Climate change

Over time, climate change has become one of humanity's most serious global problems, which can only be mitigated through joint efforts the world's governments and private actors. Climate change not only causes temperatures to rise but also leads to droughts, water shortages, wildfires, rising sea levels, floods, melting polar ice caps, catastrophic storms and a decline in biodiversity, among other things.[3]

The negative effects of climate change do not affect different regions in the same way: warming may be much more intense in the middle of continents than near the oceans, while low-lying areas are threatened by sea level rise. It is estimated that 75–250 million people in Africa could be affected by drought and drinking water

[3] UN: *Fast Facts: What is Climate Change?* Climate Action. https://www.un.org/en/climatechange/climate-fast-facts. Downloaded: 9 August 2024.

shortages.[4] Meanwhile, pollutant emissions are not highest in the regions where the consequences are most severe. Most pollutant emissions (or consumption) occur in developed countries, which are less affected by the consequences due to their location. According to *Chancel's* (*2022*) calculation, the top 10 per cent of the world's population is responsible for 50 per cent of global pollution.

The Paris Agreement was signed by 55 countries in 2015, agreeing to keep the global average annual temperature rise well below 2°C compared to pre-industrialisation levels and to make efforts to limit the increase to 1.5°C. To achieve this, greenhouse gas emissions must be reduced by 43 per cent by 2030 compared to 2019 levels, which can be achieved in most regions with zero carbon dioxide emissions. According to UN calculations, maintaining current greenhouse gas emission levels would cause the average temperature to rise by 2.5–2.9°C.[5]

Investments in the green transition are steadily increasing on the part of both the public and private sectors, but they still fall well short of the level needed to achieve zero emissions. According to calculations by *Naran et al.* (*2022*), while USD 364 billion was spent globally on the green transition in 2011, this figure rose to USD 665 billion in 2020, financed roughly equally by the public and private sectors. However, according to IMF calculations, the private sector accounted for more than 75 per cent of total investment in 2020, while in developing countries this ratio is less than 50 per cent. However, achieving zero emissions also requires an increase in private investment in developing countries. *Black et al.* (*2023*) found that USD 900 billion in climate investment was made in 2020, but to ensure zero emissions by 2050, an annual investment of nearly USD 5,000 billion would be needed to be achieved by 2030.

Governments face two types of costs in relation to climate change. On the one hand, they must finance the transition to zero emissions; on the other hand, adaptation costs will also be increasingly high, as they will have to cover the costs of restoration following increasingly frequent forest fires or floods, for example (*IMF 2023*). The increasing costs can be covered by special revenues, such as green taxes, resource reallocation or increasing public debt, which raises questions of fiscal sustainability.

A new, special government source of funding for the green transition is carbon taxes and fees from the Emissions Trading System (ETS), which generated USD 100 billion globally in 2024, doubling the 2019 level (*World Bank Group 2025*). Currently, ETSs and carbon taxes cover about 28 per cent of global greenhouse gas emissions. The revenues generated from these are often used for specific, predetermined purposes,

[4] UCAR Center for Science Education: *Climate Change: Regional Impacts*. https://scied.ucar.edu/learning-zone/climate-change-impacts/regional
[5] UN: *Fast Facts, Temperature Rise?* Climate Action. https://www.un.org/sites/un2.un.org/files/2025-11-11-fast-facts/TemperatureRise_FastFacts.pdf. Downloaded: 9 August 2024.

thereby helping to increase their acceptance. Carbon taxes levy a tax on pollutant emissions and are not yet as widespread as traditional green taxes such as those levied on energy, environmental impact and transportation. As the green transition progresses, these traditional tax bases will shrink. For example, excise duties on fuels may disappear if the transition to electric cars is completed and the emissions trading system (ETS 2) for fuels, currently planned for 2028, is implemented.

In addition to implementing green investments, regulation is an important tool for government, which can impose energy efficiency rules or introduce systems that promote the circular economy, such as the extended producer responsibility system. In addition, governments can review their previous policies, as environmentally harmful companies still receive significant government support, and withdrawing support from these companies could help the transition (*Avgousti et al. 2023*).

Private investment can be increased not only through government regulation or incentives but also through customer demand for environmentally friendly products. Although such demand is growing steadily and customer surveys show rising demand, actual purchases still fall significantly short of projections. One reason for this is that although customers consider environmental awareness to be important, when it comes to making a purchase, they still choose the cheaper product (*White et al. 2019*). Governments can therefore play a key role in reducing the price of environmentally friendly products through subsidies or tax relief and in providing investment support to producers so that they can manufacture such products efficiently and at a cheap price, thereby increasing their competitiveness.

2.3. Technological and data revolution

In the series of technological revolutions, we are currently facing the revolution of digitalisation and artificial intelligence.[6] The question, however, is who will provide the necessary investment resources for this.

During technological leaps, the government has traditionally been an active supporter of basic research, which can later form the basis for essential market technologies. Government-funded innovations were not typically aimed directly at economic goals, but contributed to the creation of technologies such as the internet, LED lights, GPS, radar, wireless communication, etc. Thus, government-funded research represents a technological breakthrough in the economy and is of greatest benefit to the country where the basic research was conducted. Throughout history, the United States has gained global technological superiority through government support for innovation. During World War I, the government played a significant role in innovations in aviation and electronics. However, until the

[6] *Bughin et al.* (*2018*) estimate that the use of artificial intelligence and smart devices in industry and services could increase global GDP by a total of 16 per cent by 2030.

start of World War II, private companies were the driving force behind innovation. World War II, again, brought about a huge change, and the federal government placed much greater emphasis on supporting innovation than before. Centralised, large research institutes were established to support innovation in a number of industries, including electronics, pharmaceuticals and aerospace. The threat posed by the Soviet Union led to a further increase in government spending on innovation, and by the early 1960s, the US federal government was spending more on innovation than all other countries' governments and businesses combined (*Atkinson – Foote 2019*). This huge expenditure resulted in the global technological superiority of the United States in a number of key industries. Within government innovation spending, expenditure on the development of military technologies stood out, contributing significantly to the establishment of the most important technology centres (Silicon Valley, Boston). Although we associate modern technological successes with private companies, they have made use of government innovations – for example, research into Tesla's battery and solar cell technology was funded by the US government, and the touchscreen that made the iPhone a success was developed by the military. In the past, basic research carried out by the government and market-driven innovation by the private sector complemented each other. The question is what their relationship will be in the future.

A more indirect, but equally fundamental relationship is that between government activities and innovation, in that the government can encourage development by ensuring fair competition and protecting intellectual property. In addition, the development of human capital is also largely a public task, primarily through public education, but also through higher education in many countries.

The government can also benefit from the technological revolution. Artificial intelligence, machine learning and similar technologies can increase the effectiveness of public policies, for example, by detecting tax fraud, calculating the social return on investment and generally processing large amounts of data. In addition, these technologies can even support budget planning and implementation as well as government liquidity management.

Digitisation reduces companies' compliance costs by simplifying tax returns and statistical data reporting through the use of secondary source data, such as big data. In Hungary, the introduction of online cash registers has significantly reduced the amount of unpaid VAT, also according to international surveys, thus contributing to a sustainable improvement in budgetary balance and fairer competition by reducing the shadow economy (*Baksay – Szőke 2020*).

In addition to exploiting technological advantages, we must also mention the reduction of risks in relation to government involvement. More and more people are encountering potentially harmful or unreliable digital content: in 2024,

1.3 billion people were affected by cyberattacks, compared to only 343 million in 2023. In 2024, the rate of data leaks increased by 211 per cent compared to the previous year.[7] According to the EU Cybersecurity Agency (ENISA), ransom demands resulting from cyberattacks increased from EUR 13 million in 2019 to EUR 62 million in 2021, and the average ransom amount doubled from EUR 71,000 in 2019 to EUR 150,000 in 2020 (*ENISA 2022*). Government regulation, development and education can help prevent these. Only governments can effectively ensure and regulate the protection of personal data and data security.

2.4. Economic inequality

The richest 10 per cent of the world's population receives 52 per cent of the world's income, while the poorest half of the population receives only 8.5 per cent of income. Inequality is even greater in terms of wealth stocks. If we look at accumulated wealth, the poorer half of the world's population owns only 2 per cent of global wealth, while the top 10 per cent holds 76 per cent of total wealth (*Chancel et al. 2022*).

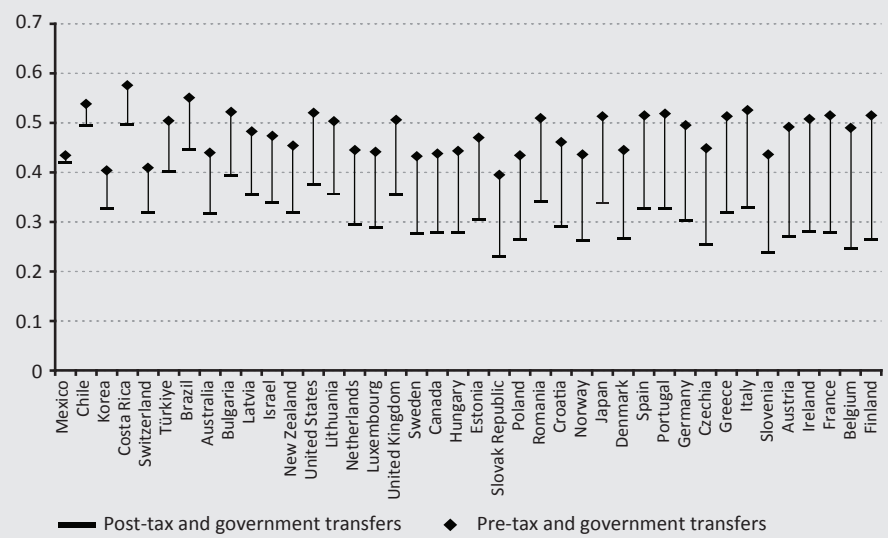
Inequality between countries rose steadily from the early 19th century to the 1980s, in parallel with the establishment of Western countries' economic superiority over the rest of the world. According to calculations by *Chancel et al.* (*2022*), inequality between countries has been steadily declining over the past 40 years, thanks to the fact that catching-up regions are growing faster than developed countries. As a result, inequality between countries has moderated and returned to the levels of the 1910s and 1920s. However, inequality within countries is following the opposite trend. From the beginning of the 20th century, inequality declined, with middle class growing and extreme poverty decreasing. Nevertheless, this trend reversed, and inequality rose from the 1980s to the 2010s, but since then, the level of inequality has stagnated at around the level seen at the beginning of the 20th century. Inequality within countries does not show a direct correlation with a country's income ranking. Among high-income countries, inequality is very high in the US, while it is very low in Sweden. Among low-income countries, inequality is extremely high in Brazil and India, while it is relatively low in Malaysia and Uruguay (*Chancel et al. 2022*).

Income inequality can be considered a natural consequence of a market economy and competition, as it encourages better performance and competition. However, excessive inequality causes significant welfare losses because it negatively affects social (intergenerational, career, income) mobility and cohesion and jeopardises the sustainability and inclusive nature of growth.

[7] Source: Reports by The Identity Theft Research Center: 2023 Annual Data Breach Report (https://www.idtheftcenter.org/publication/2023-data-breach-report/) and 2024 Annual Data Breach Report (https://www.idtheftcenter.org/publication/2024-data-breach-report/)

The government can and does contribute significantly to reducing inequalities. Economic policy can reduce inequality through income redistribution, targeted subsidies, and an adequate and widely accessible health and education system (*Dabla-Norris 2015*). *Figure 2* shows the Gini index in 2020 before and after taxation and transfers[8] in 40 countries. Income equality increased after taxation in all countries, but there are large differences between them. The effect of redistribution is highest in Finland, Belgium and France, while in Mexico, it is close to zero. Investing in human capital can reduce inequality as well as increase a country's competitiveness if it strengthens social mobility through breakthrough points.

Figure 2
Trends in the Gini index (2020)



Note: Countries are ranked according to the difference before and after taxation and transfers. Data for Japan is from 2021, data for Denmark is from 2019.

Source: OECD

2.5. Security and defence policy

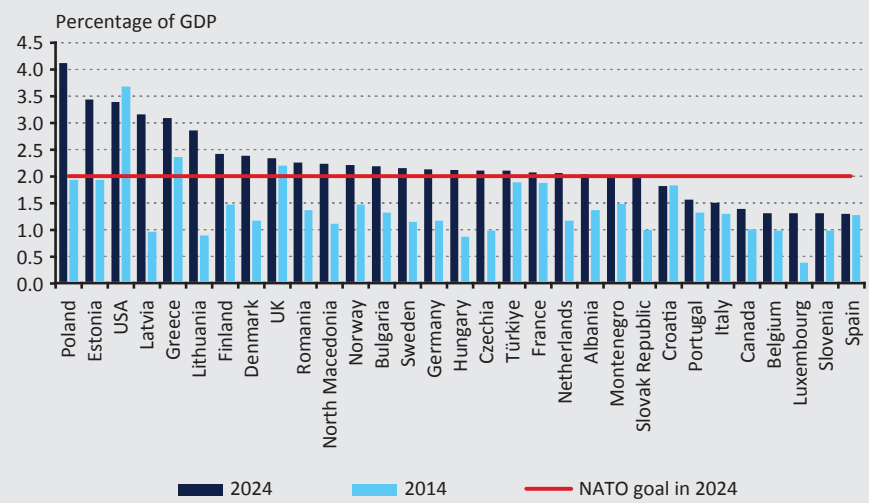
The number of armed conflicts has been on a downward trend since the 1990s, and the number of victims affected by conflict already declined in the 1980s. Since 2020, the trend appears to be reversing, with 2021, 2022 and 2023 being the three most violent years in terms of combat deaths since the end of the Cold War. During this period, a total of 600,000 persons lost their lives as a result of events in Ukraine, Ethiopia and Gaza (*Rustad 2024*). In addition to armed conflicts, competition for resources is intensifying, with economic weight and potential military action both

[8] The Gini index is a measure of income inequality within a country, with a value of 0 representing complete equality and a value of 1 representing one person owning all income.

playing a significant role. In addition to precious metals, there have been 785 violent conflicts worldwide since 2020 over access to clean water, for example.[9] New areas to be conquered, creating competition and conflict, include Antarctica, deep-sea mining and the control of outer space. In the latter case, unlike in the first space age, private investors have now entered the competition.

For the above reasons, global defence spending is on the rise. Defence spending as a percentage of GDP in NATO member countries increased by an average of 42 per cent compared to 2014. Poland had the highest defence spending in 2024, at 4 per cent of GDP, ahead of the US, where it accounted for 3.4 per cent of GDP. At the NATO summit in The Hague in January 2025, member states agreed that by 2035, they must spend 5 per cent of GDP on defence, but in 2024 one-quarter of the member states had not even reached the NATO minimum of 2 per cent required at that time (*Figure 3*).

Figure 3
Defence spending by NATO member countries



Note: 2024 data based on NATO (SIPRI) estimates.
Source: NATO

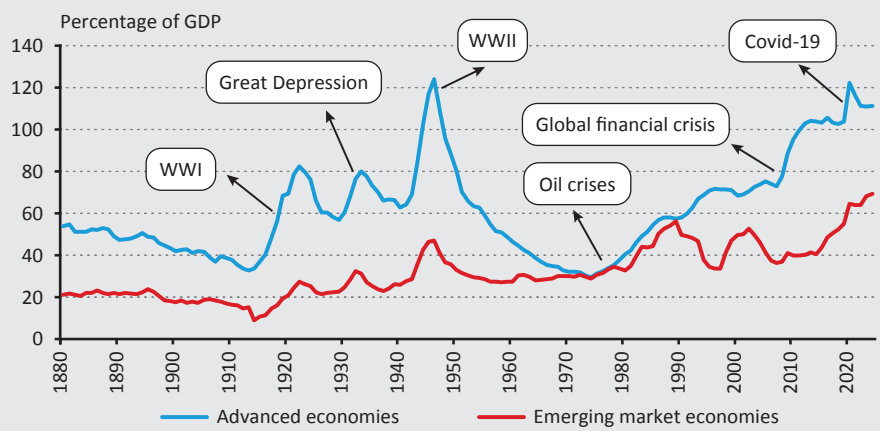
Security policy is almost entirely a government responsibility; thus, an increase in spending in this area also entails an increase in government spending. A reduction in defence spending would only be possible if geopolitical tensions were to ease.

[9] *Water Conflict Chronology*. Pacific Institute. https://www.worldwater.org/conflict/map/

2.6. Increased public debt burden

As a result of government crisis management measures following the coronavirus pandemic, global public debt ratios have risen to near historic highs. However, the sustainability of debt varies from region to region. Debt levels in developed countries have reached levels not seen since World War II, exceeding 110 per cent of GDP, and this figure has quadrupled since the 1970s. Although the level of indebtedness is high, debt crises are less common in these countries, as they typically finance themselves in their own currency and from domestic sources. Over the past 150 years, we have seen six major waves of indebtedness; the current upward trend began in the mid-1970s (*Figure 4*). The public debt of developing countries has risen to unprecedented levels, approaching 70 per cent of GDP, and is forecast to continue to grow at a faster pace than that of developed countries. Meanwhile, as global yields rise, the cost of financing and rolling over debt is also increasing, disproportionately affecting developing countries, which are more exposed to financial market volatility and pay higher risk premiums on their debt instruments.

Figure 4
Public debt ratios in developed and developing countries (1880–2024)



Source: IMF

In the low-yield environment of the late 2010s, which was thought to be permanent, the increase in public debt did not place a significant burden on budgets. However, the inflation that has characterised the recent period, followed by rising yields, has posed challenges for fiscal policies in many countries (*Gaspar et al. 2023*). During the recovery following the Covid crisis and the period of higher-than-expected

inflation, public debt remained high in most countries, partly due to measures taken to boost growth and mitigate the negative welfare effects of surging inflation.

Most analysts believe that the global increase in public debt will not stop. In the short term, high interest rates, defence spending due to military conflicts and public investments needed for the green transition are limiting governments' room for manoeuvre, while in the long term, climate protection and an ageing society pose challenges: pension and healthcare costs are rising, while tax revenues are falling (*Adrian et al. 2024*).

2.7. Impact of globalisation on tax bases

In the following sections, we examine the economic effects of globalisation, which are also transforming the tax bases that determine budget revenues. Countries compete for the taxes of global companies, which relocate their tax payments to the country with the most favourable tax regime, regardless of the actual location of their value-creating activities, thereby minimising their taxes. Although the effective corporate tax rates of large corporations are close to 1 per cent according to some estimates, they still represent a substantial payment for each country (*Hebous 2020*). The OECD estimates[10] that corporate tax avoidance amounts to USD 100–240 billion per year, which is 4–10 per cent of total global corporate tax revenue. Low taxation of large corporations further increases inequalities within and between countries, as the owners of these companies earn high incomes at low effective tax rates and typically transfer this income out of the country. By contrast, local SMEs have more limited opportunities for tax avoidance, which puts them at a competitive disadvantage compared to large global corporations. Although regulatory authorities are trying to enforce their tax rules on multinational companies, the latter have a wide range of tools at their disposal to optimise their tax payments (e.g. international tax advisors).

Led by the OECD and the G20, 137 countries signed an agreement in 2021 on a global minimum corporate tax rate to contribute to the more equitable taxation of digital and large corporations, with an additional 10 countries joining by the summer of 2024. The agreement is based on two pillars. The first pillar was intended to apply to digital economic operators by broadening the concept of permanent establishment, on the basis of which, in addition to physical/legal presence, the geographical distribution of the consolidated turnover of companies and groups of companies could also be taken into account for taxation purposes.[11] The detailed rules are taking a long time to be finalised; therefore, they are not expected to be

[10] *Base erosion and profit shifting* (BEPS). https://www.oecd.org/en/topics/policy-issues/base-erosion-and-profit-shifting-beps.html. Downloaded: 9 August 2024.

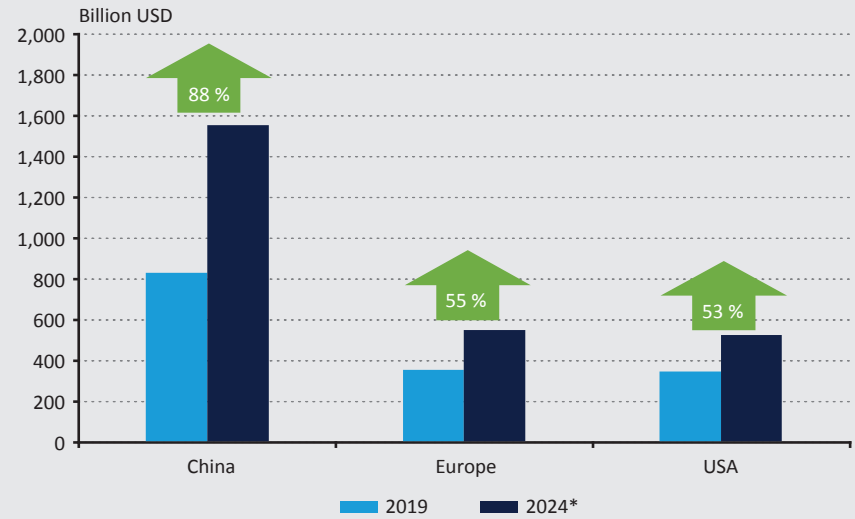
[11] Digitalisation raises the taxation issue that it is difficult to determine the location where the tax liability arises. This could reduce tax revenues in some countries while increasing them in others, thereby increasing related inequalities.

introduced anytime soon. Under the second pillar, companies with global revenues exceeding EUR 750 million will be required to pay a minimum corporate tax rate of 15 per cent globally. The aim was to encourage companies not to relocate to other countries in search of more favourable tax rates (*MKVKOK 2024*). The second pillar of the agreement has been transposed into the legal systems of the member states, but as the first pillar has not yet been implemented, digital companies still do not pay tax in the countries where they provide services. The adoption of the pillar is hampered by the fact that the United States has no interest in it, as most global technology companies operate there; thus, if the pillar were implemented, the country could expect a significant tax loss. Taxing these companies is further complicated by the fact that they often do not have traditional products that users pay for but instead are able to monetise the data they collect from users, making it particularly difficult for regulators to determine how much value added the companies have created in each country (*Enache 2024*). The United States and the other members of the G7 group agreed at the end of June 2025 to exempt US companies from the global minimum corporate tax rate. According to the statement announcing the exemption, the G7 group is seeking to create a parallel system that is acceptable to the US government and ensures a level playing field between countries. However, some experts consider these developments as hollowing out the 2021 agreement.

With the emergence of large global corporations and the spread of free markets, the realisable consumption tax may shift along their Laffer curve.[12] Consumers can cross the border to shop in a neighbouring country with lower consumption taxes, if it is close enough. The spread of online commerce may have an even greater impact. In recent years, the global market has been flooded with cheap online stores offering products at much lower prices than local retailers, with low shipping costs. The volume of Chinese e-commerce has increased by 88 per cent in five years, while in Europe and the US, it has increased by around 55 per cent (*Figure 5*). Local tax authorities have less control over global web companies, which are thus more likely to optimise their tax payments and pay taxes where the rate is lowest.

[12] According to economic theory, there is an inverse U-shaped relationship between the tax rate and the amount of tax collected, meaning that tax revenue increases for a while, but once it reaches its maximum, further increases in the tax rate result in declining revenue. This is known as the Laffer curve (*Meyer 1981*). The reason for this is that an increase (decrease) in the tax rate changes the behaviour of individuals/companies, causing them to consume/produce less (more), and the increasing tax burden also provides a stronger incentive for tax evasion.

Figure 5
Sales volume from e-commerce



*Note: *forecast.*
Source: Compiled based on Statista Digital Market Outlook

Digitalisation also makes tax bases more elusive. Income taxes are linked to the place of value creation, the determination of which, even before the wave of digitalisation, posed serious difficulties with the emergence of global production chains, because in an integrated international production chain it is extremely difficult to determine exactly how much of the value of the final product can be attributed to each stage of the production process. At the same time, consumption taxes are levied in the country of final consumption, which is usually easier to determine than the place of value creation (*Gerlaki et al. 2025*).

3. Conclusion

The global trends emerging in the 21st century pose new challenges for economies and societies. Due to their complexity or scope, many of these challenges require public policy and budgetary action, in addition to individual involvement. Among the most significant of these are ageing, climate change, digital revolution, the increasing importance of security policy, growing economic inequality, the rising burdens of public debt and the impact of globalisation on tax revenues. In this essay, we examined the impact of these simultaneous, large-scale trends on government budgets.

The global challenges presented are closely interrelated and require complex solutions. What they have in common is that they fundamentally increase the burden on the budget, but they differ in terms of the time frame they cover and the extent of the government response they require. For example, in developed countries, security policy as a whole and dealing with the effects of ageing are largely public tasks, but the costs of digital transition may be concentrated more in the private sector, which can potentially profit from it. Preventing and mitigating climate change is an area that requires not only cooperation between the government and the market, but also joint action at the international level. Finally, the rising burden of debt and the increasingly volatile tax base resulting from globalisation can be considered strictly budgetary issues, as they can become effective constraints.

These constraints also have an impact on potential additional expenditure, as it can be financed from taxes, reallocations, or fiscal deficit and debt increases. These options are all limited from an economic or sustainability perspective (*Baksay – P. Kiss 2023*). The widely held assumption that, with the exception of interest rates and ageing-related expenditures, all other items can be assumed to remain unchanged, because poverty in old age is increasing among various groups within an ageing society, and climate change will also disproportionately affect those with lower incomes. Global challenges affect different regions to varying degrees, but *Fanelli*'s (*2018*) model provides a unified framework for the potential role of government. In this model, in addition to debt and tax constraints, at each point in time, redistributive expenditures compete with other budget items. A solution must therefore be found that serves the dual purpose of fiscal balance and effective adjustment. To this end, the role of government in the economy needs to be reconsidered, with the emphasis placed as much as possible on low-cost but effective measures and regulations with high "leverage".

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How Banks' Tasks Regarding Their Financed Carbon Footprint Is Misunderstood by EU Regulation*

Gábor Szigel

Regulation in the EU makes banks responsible for the greenhouse gas (GHG) emissions of their borrowers and thus tries to use them as leverage to nudge polluting industries into the carbon-free transition. For lack of better alternatives, this occurs based on metrics that are neither reliable nor robust. While welcomed by the industry, the European Commission's recent omnibus packages aimed at simplifying sustainability legislation will also probably not change that situation materially. Although it is perhaps well-intended, this approach assigns banks a task which they are not qualified for. It is unsurprising that the entire initiative has resulted in bureaucratic formalities in banks' reports rather than substantive progress. It is not the best way to get credit institutions engaged in the green transition. Instead, banks should focus on what they are best at: lending, and more specifically, on lending for projects that advance the carbon-neutral transformation of the economy.

Journal of Economic Literature (JEL) codes: G21, O13, P18, Q50

Keywords: financed carbon footprint, financed greenhouse gas emission, green transition

1. Introduction

For some time now, EU policymakers have targeted the banking system through its credit decisions, in order to enforce the transition towards a greener, more sustainable economy. This may have seemed a good idea: use the banking system as an efficient lever to combat powerful lobbies of polluting industries (such as oil), according to the motto: "just cut their access to finance, and then you do not have to bother with complex, politically costly direct restrictions on them."

* 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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Regardless of how appealing this may appear at first sight, in this article, it is argued that a) there are deep-rooted conceptual problems with this approach; and b) it is based on metrics which are inherently flawed and inappropriate for practical decision-making.

2. What exactly does EU regulation request from banks regarding their carbon footprint?

There are many regulatory and supervisory initiatives in the EU that try to push banks into a role of policing the green transition of the economy.

First, the Corporate Sustainability Reporting Directive[1] (CSRD) and its underlying supplementary regulations, such as the European Sustainability Reporting Standards (ESRS), request significant (large and/or listed) banks to report the current value of their *financed* greenhouse gas (GHG) emissions and set reduction targets for such, along with a corresponding action plan[2] to reach those targets. The word "financed" is important here: a bank's *financed* GHG emissions refer to the emissions released by the *borrowers* of the bank (as opposed to the bank's *own direct* GHG emissions, which are in the scope of the regulation as well, but these are so small compared to *financed* emissions that they hardly matter[3]). How those financed emissions must be calculated – which is, as we will see, in itself problematic – is defined by the PCAF (Partnership for Carbon Accounting Financials) Standard (*PCAF 2022*),[4] which used to be a voluntary standard, but which was basically turned into an official technical guidance within the EU by the CSRD.

To make it clear: CSRD/ESRS are not bank-specific regulations, as they cover other large, non-financial companies as well. In fact, for banks, the biggest challenge with CSRD/ESRS is that these regulations take an approach which is designed for the characteristics of typical non-financial corporations: they implicitly assume that enterprises control the bulk of their GHG emissions (whereas banks – as we will see later – do not) and can thus take concrete actions with sizeable costs/investments and predictable results (whereas for banks, reducing their financed carbon footprint does not require large investments, only business-as-usual credit decisions, but with unpredictable results). Also, CSRD/ESRS is "only" a reporting requirement: thus, banks could theoretically choose not to report any financed GHG reducing

[1] Directive (EU) 2022/2464 of the European Parliament and of the Council of 14 December 2022 amending Regulation (EU) No 537/2014, Directive 2004/109/EC, Directive 2006/43/EC and Directive 2013/34/EU, as regards corporate sustainability reporting.
[2] In CSRD terminology: "transition plan for climate change mitigation".
[3] As *Angelico – Bernardini* (*2025*) states for a sample of large, publicly traded euro area banks: "Scope 3 emissions (…) account for the largest share of the overall emissions (…), with an average share of 86% in 2022, which is even higher for most of the banks (…), although there are a few exceptions for which data are arguably misreported or poorly estimated."
[4] While there is a new version of the PCAF Standard (Part A – Financed Emissions 3rd edition (2025)), the effective EU legislation still refers to the previous version, the 2nd edition from 2022.

plans and actions. However, combined with pressure from supervisory authorities and the public, this is not really an option for them.[5]

There are also bank-specific regulations. The EU's Capital Requirements Directive (CRD) requests banks to prepare a transition plan to manage their ESG risks. Based on the CRD, the European Banking Authority (EBA) issued its guidelines[6] on the same topic. Although the CRD/EBA focus mostly on how banks should protect *themselves* from risks related to climate change, it also imposes tasks on them such as assessing large borrowers' "transition plans" (to a carbon-free economy), and "engaging" with them, so they reduce *their* greenhouse gas emissions.

Additionally, we have the activist approach taken by some financial supervisory authorities in the EU. Some use the "carrot", such as the central bank of Hungary, which provides capital requirement relief for green loans (*Bethlendi – Holczinger 2024*), while others, such as the European Central Bank (ECB), take the "stick" approach and push European banks to put pressure on the rest of the economy to progress with the green transition. As ECB board member Frank Elderson said at an ECB Industry Outreach event in 2023 (*ECB 2023*), "we insist that continued non-green lending without incorporating in [banks'] assessments and decisions clients' credible and science-based Paris-aligned transition plans is no longer compatible with sound risk management." This statement clearly suggests that – according to the supervisor – banks should assess not only borrowers' riskiness, but also the credibility of their plans to reduce their GHG emissions and switch to green(er) technologies in line with the Paris Agreement.

3. Banks should thus do their part to combat climate change. What is wrong with that?

Naturally, it is completely welcome that banks should do *what they can* to contribute to the green transition. But the emphasis here is on "what they can", because banks have very limited capabilities to do what regulation expects of them: to assess which greenhouse gas (GHG) emissions of their borrowers are justified and aligned with the Paris Agreement and which emissions are not. After all, the targets of the Paris Agreement have not been broken down to the company or household level. Even worse: global alignment with the Paris Agreement can be ensured by an endless number of combinations of different actors' different GHG-reductions. Thus, in strictly technical terms, for an individual company or household, there is no such

[5] What would have gone over reporting obligations, was the Corporate Sustainability Due Diligence Directive (CSDDD). However, as at the time of closing this manuscript (15 December 2025), it seems that the European Commission's recent omnibus package will abandon the obligation of large companies to not only *report*, but also mandatorily *prepare* a transition plan focusing among other on reduction of GHG emissions. This keeps the CSRD-regulation in its current *soft* form, as companies will still only be requested to report what they plan and do, but they will not be told what to plan and do.

[6] EBA/GL/2025/01: Guidelines on the management of environmental, social and governance (ESG) risks.

thing as “alignment with Paris”, because alignment always depends on the efforts of the others as well.

Which production technologies with material GHG emissions can be abandoned or replaced by green alternatives and when, is an enormously complex question. While it is easy to point the finger at carbon-intensive sectors, in reality, we also need many of the products from those sectors, even for progress in the green transition. For example, the production of steel is clearly very carbon-intensive, but we need steel to build wind turbines. It is no coincidence that even net-zero scenarios – such as that of the International Energy Agency (*IEA 2024*) – do not project a decline in steel production by 2050 (and also do not even foresee absolute zero GHG emissions from steel production, meaning that some producers will still be “allowed” to emit GHG even after 2050).

Furthermore, there is a disturbing characteristic of net-zero scenarios: they expect the reduction of global GHG emissions after 2030 to a large extent by means of technologies that are not yet commercially mature (*McKinsey 2023*). In fact, mankind does not have a clear plan for net zero. Even when there are promising alternatives to polluting technologies, the application of those may come with costs and trade-offs.

Decisions on costs and trade-offs, on accepting or refusing the risks resulting from new technologies, and on accepting the redistributional effects of them, etc. are typically those that are best delegated to policymakers ideally with industry insights, who have (again ideally) both the necessary knowledge and political mandates to take them. Banks do not have those skills, and therefore they should not be pushed into the roles of such decision-makers.

To illustrate the absurdness of the idea that banks should pave the decarbonisation pathway of their borrowers through targets in their loan portfolios’ financed GHG emissions, take the example of the ozone-killing gases of freon. When the international community realised that freon damages the Earth’s ozone layer, they simply banned freon by the Montreal Protocol – instead of mandating banks to calculate their *financed freon emissions*, to publish relevant reduction targets and to push borrowers to use their refrigerators less. Obviously, this was possible only because freon-based technologies were easier to replace than GHG-based ones – so yes, this time is different and the decisions are tougher. However, outsourcing them to hundreds of banks – to institutions without any competitive advantage on such matters – will not make those decisions easier.

4. Do risks justify financed GHG emission targets of banks directly?

The pressure on banks to push their clients' decarbonisation is often justified by the argument that this is also in banks' own interest: as the green transition progresses, polluting industries will become a source of financial risk. This is called "transition risk": the risk that the "losers" of the green transition, i.e. companies with obsolete, polluting technologies will face declining sales, reduced profitability or even regulatory prohibitions and thus will not be able to pay back their loans, which remain in banks' balance sheet as "stranded assets". Sometimes references are also made to a more indirect chain of risks: if banks do not push enough their polluting clients towards net zero, then the doomsday scenarios of climate change wiping out civilisation – together with the banks themselves – will become more probable. However, this argument is so general and could be applied to a number of other end-of-the-world type risk factors that the focus is more often on the above-mentioned transition risks, which are of direct and short-term nature.

Some financial supervisory authorities (such as the ECB or the EBA) must refer to risks if they want to impose environment-related requirements on banks, because their legal mandate does not allow otherwise. However, even supervisors that received an explicit legal mandate on sustainability-related matters – such as the Bank of England or the Magyar Nemzeti Bank (the central bank of Hungary) – must reconcile that with their more traditional risk-focused goals, especially that of financial stability. Whether it is a good idea to extend financial authorities' mandate to environmental sustainability was discussed when those decisions were made in the relevant countries (*Deák – Sárvári 2023*). Some banking experts tend to oppose the dilution of prudential regulation with climate-related objectives, as demonstrated by two experts at the EBA (*Castren – Russo 2024*), but there is political pressure on supervisory institutions that is hard to resist. Either way, supervisors take up arguments referring to risks, in order to address banks' financed GHG emissions.

This is also supported in academia. As *Kiss et al.* (*2025*) showed, there has been a flood of scientific articles focusing on the relationship between companies' ESG performance[7] (although this is a wider concept than the matter of GHG emissions) and their credit risk, with the number of articles almost doubling each year since 2020. It seems there is a wide consensus in these papers that corporations with better ESG performance are somehow also better in financial and risk terms (cf. a good literature review by *Galeone et al. 2025*), though it seems to be less clear whether this is causality or just correlation. Without taking a stand, we would merely point out that the latter would also not be unsurprising: attitude research

[7] ESG – environmental, social and governance factors of corporate behaviour. What the ESG performance actually measures is not straightforward, but we will not go into discussion of this particular topic.

(e.g. *Guzmán – Kóczán 2025*) shows that people with more future-oriented attitudes proved to be more willing to pay for costs of environmental policies.[8]

The climate change stress testing models of central banks also make the explicit assumption that more carbon-intensive industries are exposed to more transition risks (for a summary of the international practice, see *Várgedő 2022*). In this approach, any regulatory punishment of the GHG emissions of banks' borrowers have an impact on them like a carbon tax: the more a company uses the taxed factor (in this case, emitted GHG), the more its profits come under pressure and turn into a risk for the bank. Unless it can pass on burdens to end users.

The key point here is that many carbon-intensive technologies are currently irreplaceable, as there are no viable green alternatives, but their products are still needed by the economy. That is exactly the reason why regulators cannot simply ban them and solve the climate crisis. For those products, demand-elasticity is low: end users will buy them even if the price increases (due to a higher carbon tax or any other reason), leaving the production company with more buffers to compensate against transition risk.

Therefore, when assessing the transition risk of a carbon-intensive borrower, one should distinguish among carbon-intensive companies based on the substitutability of their products: if you have a borrower (e.g. a cement factory) whose products are currently irreplaceable and demanded by the market, with no green alternative on the horizon, then lending to this company is not particularly risky (at least: not yet). On the other hand, a low-carbon profile will not necessarily protect a borrower from transition-related risk: take the example of a hairdresser in a small town where the largest employer, a coal-fuelled power plant, will soon be closed.

Clearly, it is in the banks' best interests to keep an eye on their carbon-intensive clients and avoid those who face the risk of obsoletion of their non-green technologies. Nevertheless, there is nothing really new in this: managing risks from technological transitions has always been part of the banking business, with or without regulatory pressure. Technology and industries are changing constantly: a paper found that the majority of industries in the USA saw either their core assets or their core activities threatened by obsoletion in the past 20 years (*McGahan 2004*), and this paper was published 20 years ago! Just take the example of digitalisation: it has destroyed whole industries since then. Nevertheless, banks were able to avoid systemic losses from it, and in fact, systemic banking crises do not tend to be rooted in technological changes in the real economy.

[8] Although this research focused on individuals rather than companies, its conclusions can be applied to companies as well.

Thus, banks' risk management must certainly cover transition risks – as all other risks resulting from climate change – appropriately, but managing real-word risk is not the same as assessing the appropriateness of borrowers' GHG-reduction plans and technological choices, or deciding on which borrower emits just too much GHG compared to its economic benefits from a point of view of the common good. The former is a business-as-usual function of banks, the latter is much closer to that of an environmental authority. However, EU regulation tends to also request the latter from banks.

5. Banks' financed carbon footprint is based on troublesome metrics

In addition to the above, the figures based on which banks measure their financed carbon footprint are anything but reliable. This is well-known within the industry, while public talk about it is rather rare, although not unprecedented: e.g. two authors at the Bank of Italy (*Angelico – Bernardini 2025*) thoroughly documented empirical inconsistencies in large euro area banks' financed GHG emission data.

To understand why these metrics are troublesome, we have to look at the details of how banks calculate their financed GHG emissions according to the PCAF Standard.

First of all, banks must quantify the GHG emissions of their borrowers. Three types of emissions must be included:

- direct – so-called Scope 1 – GHG emissions (from fossil fuels burnt directly by the borrower);
- indirect – so-called Scope 2 – GHG emissions (related to the electricity consumption of the borrower); and
- value chain – so-called Scope 3 – GHG emissions (emitted in the value chain of the borrower).

Let's take the example of your favourite restaurant as a borrower: the natural gas it burns for heating the place translates into a Scope 1 emission; the coal that was burnt by the local power plant selling electricity to the restaurant is Scope 2; and all of the GHG emissions that were necessary to produce, deliver and finally put a glass of soda in front of you on the table are Scope 3 emissions.

How do banks know those GHG emissions of their borrowers? Well, for most of them, they don't. While there are a few big companies that measure and report their GHG emissions (mostly based on the requirements of the CSRD regulation), for most borrowers, GHG emission figures are rough estimations based on the industry classification or other characteristics of the loan/borrower.

Taking the example of your restaurant: the bank would see that its statistical activity classification code (NACE code) is I56 ("Food and beverage servicing activities"). It would then take, for example, some revenue-related carbon-intensity factors showing how much the Scope 1, 2 and 3 emissions were for companies with a similar NACE code in your country per EUR 1 million of revenue and multiply that intensity factor by the reported revenue of the restaurant. Where do banks get these revenue-related carbon intensity factors from? They are estimates based on high-level (sectoral-level) macroeconomic statistics, mostly on the so-called input-output matrices and they suffer from a number of weaknesses: global input-output matrices that capture international supply chains are available with a huge time delay (depending on type, 5–10 years) and they are vulnerable to a series of reporting uncertainties (just to name one: correct mapping and breakdown of companies' actual activities into statistical categories of the activity codes).

Thus, the estimation uncertainties in banks' overall financed carbon footprint will inevitably be large, which makes those figures not very ideal for setting targets. After all, if you have a metric with a confidence interval of say +/–50 per cent, then setting a reduction target of –25 per cent or so for it is not very reasonable.

6. Metrics will also not improve over time

One common justification for this practice is that metrics will become better and more reliable with time, as more and more companies and borrowers measure and report their GHG emissions. The omnibus packages of the European Commission to simplify the requirements of the CSRD / CSDDD also address this aspect: how many (more) companies will (or will not) have to measure and report their carbon footprint and when.

However, these are false hopes. Surely, at some point, we will be able to measure the Scope 1 (direct) emissions and to estimate (but still not measure!) the Scope 2 emissions of borrowers (from electricity consumption) more precisely. But estimating comprehensive Scope 3 (value chain) emissions is an extremely complicated controlling exercise with an unlimited number of combinations of potential solutions and thus will *never* provide robust results.

To understand this, let us take again the example of your favourite restaurant with your soda on the table: that soda was delivered to the restaurant by a truck operated by a transportation company. The gasoline consumed by the truck is included in the Scope 3 (value chain) emissions of your restaurant (among a series of other emissions, of course). Now imagine that the truck delivered goods not only to your place, but to other places as well. How would one divide the GHG emissions of the truck among them? Based on cargo weights? Based on the monetary value of the cargo? What about accounting for different distances travelled? You can

surely come up with a lot of solutions, and none of them will be bad, only different, based on different assumptions – and so, none of them will be comparable. And we can complicate this even further: if the truck was run by your restaurant, then its fuel consumption would classify as its Scope 1 (direct) emission, not Scope 3. Accordingly, the emission figures of your restaurant and other ones that do not have their own trucks would not be comparable. To put this in more professional terms: vertical fragmentation of the value chain distorts GHG emission estimations.

Moreover, there is the issue of double-counting: if a bank finances both your restaurant and the transportation company delivering the beverages, then the GHG emissions of the truck will be counted at least two times in the financed carbon footprint of the bank: once, as a financed Scope 3 (supply-chain) emission of your place, and once again, as a financed Scope 1 emissions of the transportation company. Nonetheless, if the restaurant merges with the transportation company, then the same GHG emissions will be counted again only once (as a Scope 1 emission of the merged company). The point is: the double-counting issue might not even be constant over time and is definitely not independent of the vertical structures of the value chains.

We could go on and on with examples of why this type of GHG accounting of supply chain (Scope 3) emissions is just not able to provide robust and reliable estimations. Not even for a simple restaurant – now imagine this for thousands of companies with a hugely complex network of supply chain relationships.[9]

To circumvent these well-known weaknesses of financed GHG emissions, the banking industry and supervisors tried to introduce some more reliable, alternative target indicators that capture borrowers' emissions by some physical activity-based indicators capturing only selected fractions of the value chain. These are often called "alignment metrics" (based on a mandatory EBA reporting template[10]) and they show borrowers' pollution as a ratio of GHG emissions per some production metric (e.g. kg CO_2e emitted / MWh of electricity generated or tons of CO_2e emitted / tons of cement produced). These are applied mostly for the pollutive industries with usually large companies, which are obliged to report those metrics anyway, at least if they operate in the EU (because, for example, they are part of the ETS system). These alignment metrics tend to focus only on certain, more controllable parts of companies' GHG emissions (usually parts of Scope 1 or 2), not on everything. While these metrics are more reliable and robust at the borrower level, they have some disadvantages as well: as they are industry-specific, they create clusters with often

[9] To be fair: in some cases, value chain emissions can be useful for limited and special sections – but not the whole! – of the value chain in particular industries, such as car manufacturing, where it is completely reasonable to account for the fuel consumption of cars produced. But those are the exception rather than the rule.

[10] "Template 3: Banking book – Climate change transition risk: Alignment metrics" of the prudential disclosure (Pillar 3) requirements on ESG risk.

just a small number of borrowers; the indicators for different industries cannot be added up; they can cover only a fraction of banks' loan portfolios; and technically, they are not in line with requirements of the CSRD, which requests banks to cover the financed GHG emissions of *all* of their loan portfolios. In addition, they are just as exposed as the basic financed GHG emission metrics to the next big problem. which is discussed below.

7. Banks are not able to control key variables of their financed carbon footprint

Once the bank has provided a loan to a borrower, it has no strong levers to influence the borrower's GHG emissions. Thus, it is quite possible that a banker approves a loan to a company with "good" GHG profile, but a few months later, this company buys a more polluting plant or merges with a more polluting company. Cancelling such loan contracts is not an option, not only because such developments can occur even without bad intentions of the borrowers, but that would also not be very prudential: cancelling a loan contract can cause a borrower to go bankrupt, which imposes risk of financial losses for the bank as well.

There is also the issue of allocating borrowers' GHG emissions to banks. According to the relevant PCAF Standard, banks allocate a share of the borrower's total GHG emissions to themselves in proportion to the financing ratio (called the "attribution factor" in the terms of PCAF). Consider this example: if the bank's borrower emits 10 tons of CO_2 a year, and the bank finances 20 per cent of the total assets of this company, then the bank's "share" of the company's GHG emissions is 2 tons of CO_2 (=10 * 20%). Now, it is important to see here, that the bank does not fully control its share of responsibility: if the borrower's total assets decrease, then the bank's share of responsibility goes up and vice versa, despite the bank doing nothing.

It becomes even more complicated if we take the portfolio view: if a "green" borrower of a bank decides to make an early redemption on its loan, then the bank's average financed emissions (measured as per loan volume) will increase, despite the bank not doing anything wrong. Constant, unpredictable changes in portfolio composition make portfolio-level target setting for banks' financed GHG emissions (or any other type of "alignment metric") very difficult, and this would still be a problem, even if the perfect indicators for borrowers' emissions were found (which we have not, as illustrated by the previous chapter).

More practical examples could be presented, but perhaps the ones above suffice to show that the financed GHG emissions of banks rely on metrics that are neither reliable nor (fully) controllable by the financial institutions. Therefore, they cannot serve as the basis for serious decarbonisation planning.

8. Practical examples do not defy theoretical objections

One could ask whether banks did not turn out to be creative enough to fill the above-described regulatory framework with meaningful content – and prove the critics wrong. After all, since end-2024, large banks in the EU have been obliged to publish their decarbonisation targets according to the CSRD regulation.

First, while the relevant banks did in fact publish decarbonisation targets for their loan portfolio at least for 2030, upon closer examination one sees that they do not state that they can ensure achieving those targets. Most of them do not address this openly, and they add a series of disclaimers. Furthermore, there is also a typical pattern for at least a part of those decarbonisation targets: the bank takes a base year value, let's say 100 from the relatively distant past, e.g. 2019. They then set a targeted reduction rate for 2030 compared to this base year, e.g. –20 per cent, so from 100 to 80. Then they report a fact figure of 79 or 81 for 2024, so that the 2030 targets have basically been met already.

Furthermore, upon checking what concrete measures banks promise to take to reach their decarbonisation targets, one mostly sees very general, sometimes even surprising statements. For example, one bank states that it will "*engage with* [oil&gas] *clients to educate them about transition*" or "*help clients to address sector challenges*". Without questioning anyone's good intentions, one might ask whether bankers can really tell anything new to a client in oil about the transition of his/her own industry.

It is doubtful whether such targets and "action plans" promote the cause of the green transition or if they are just "cheap talk" enforced by regulation (while producing this content in banks' reports is – of course – anything but cheap). You can blame banks' reluctance "to do good" or their greed for not elaborating meaningful decarbonisation plans related to the emissions of *their clients*. Still, it is also possible that they were just simply mandated to do a job that is beyond their competence. With green-washing charges looming, the best they can do is not to promise anything concrete based on indicators they do not fully control.

The omnibus packages of the European Commission to simplify sustainability legislation – while they were welcomed by the banking industry as in fact, they bring some simplification in the sustainability reporting obligations of the EU – do not address the specific issues enumerated in the previous sections of this article: the lack of banks' competence to assess the justification of their borrowers' GHG emissions and the flawed metrics. This leaves large EU banks with heavy, difficult compliance burdens, while rigid decarbonisation commitments are pushed back in the international banking system (as US and Canadian banks leave voluntary net zero alliances).

9. What banks could really do for the climate: providing finance to green transition

It is important to emphasise that European banks should do their part in combatting climate change. However, their part should be tailored to their capabilities. According to banking textbooks, the main function of the banking system is to transform short-term savings into long-term investments by taking and managing related risks successfully (maturity transformation and risk-taking). In short, lending is banks' core competence.

There is an – often undervalued – benefit of everyone doing what their duties are. We can group people into those who actively work on solutions to climate change (climate scientists, mechanics at a solar power farm, etc.), and those who just do an average job (like the ones operating the basic infrastructure of our economy, such as food production, transportation, waste management). You might praise the heroic efforts of the former group as great fighters of climate change, but they could not thrive without the efficient work of the latter.

It should be completely acceptable, if banks' main contribution to mitigating climate change is providing loans to the green transition and all that it takes, i.e. assessing returns and risks (also, transition risks and physical risks related to climate change), defining financial conditions, etc., while keeping their depositors' money safe. It is not the job of bankers to plan companies' and households' GHG carbon footprint pathways through financed emission targets, all based on junk statistics, to decide on what technological alternatives and which emissions should be acceptable and which should not, and to actually orchestrate a complex socio-economic and technological transformation process. Giving someone an assignment which they are not capable of performing is just a waste of resources. It is not very sustainable.

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Biodiversity Finance – the Emergence of a New Field of Research*

Gergely Gajdócsi

Thomas Walker – Helena Naffa – Rajesh Kumar Tharumar – Simone Donders: Biodiversity Finance: The Economic, Operational, and Societal Impacts of Biodiversity Loss
Palgrave Macmillan, 2025, p. 426
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From time to time, a process takes place in nature as a result of which a species' population reaches the end of its exponential growth phase. The scarcity of resources forces individuals into stronger competition and more frequent confrontation, while external shocks may have more severe consequences than usual for the established equilibrium.

Humanity is currently following precisely this path. Fortunately, the process is mitigated by a number of factors, such as the organisation of our societies, the reflexive capacity of human thought and technological progress. The relative equilibrium that exists in the world today is fragile: it is threatened by two of the most significant – and mutually interacting – processes affecting the environment, namely climate change on Earth and the decline in the diversity and extent of wildlife. Although increasing attention has been dedicated to this dual crisis in recent decades, particularly to the issue of climate change, there still remains a substantial gap between the scale of the threat and both the decision-making processes and the funding of methods leading towards solutions.

Science alone is not sufficient to address these challenges, but its findings provide a key basis for making responsible decisions in the future. This is why the emergence of biodiversity finance as a field of research and a practical area of financial expertise, or some variation thereof, is of particular significance.

Quantifying biodiversity processes and examining them from an economic and financial perspective brings the natural crisis closer to the actors in economic and political life. In this way, alongside climate change, the protection of wildlife may

* 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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also be given greater weight in investor decisions, risk management frameworks, national economic strategies and supranational agreements.

The synthesis of the independently accumulated achievements of ecology and finance holds outstanding promise, the outlines of which are already visible from a few years' perspective. The book *Biodiversity Finance* offers a compelling insight into this emerging field. Through 14 selected studies, the volume presents the most important research directions and results from the first years of research on this topic. Before discussing the individual studies, I would draw the readers' attention to *Odia's* summary (pp. 115–152), which outlines the causes and current status of the ecological crisis and the international agreements aimed at addressing it.

Below, I present some of the most exciting topics raised in the book's studies. Following the structure of the book, I discuss (1) the quantifiability of ecological processes and natural capital; (2) the two-way risks between the economy and the environment; and (3) some innovative financial instruments and methods that can promote the mobilisation of financing.

Measurability

Let us imagine a bustling deciduous forest! Trees grow towards the sky, competing for the sun's rays, while herbivorous animals nibble on the leaves of young saplings. Predators lie in wait with hungry stomachs, and fungi break down the remains of dead animals. The field of ecology offers an extensive literature discussing the modelling of forest ecosystem processes.

This is complemented by ecological economics and biodiversity finance, which assign a monetary value to the goods provided by nature, known as ecosystem services. Once we can assign a well-founded value to the elements and processes of nature, they can immediately be integrated into economic models, regulatory decisions and even the plans of individual corporate projects. If nature is not merely an external factor that poses an obstacle but a valuable asset incurred as an opportunity cost, the likelihood of its transformation and destruction is significantly reduced.

In this line of research, *Hernández-Blanco's* study (pp. 61–84) examines the extent to which individual species contribute to maintaining the balanced state of ecosystems. The "health" of the environment is a fundamental condition for providing ecosystem services that are beneficial to the economy and society. The author outlines a general methodology for assessing and quantifying the contribution of individual species to the process.

Beverdam and *Scholtens* (pp. 85–112) examine how environmental indicators and metrics that determine the state of biodiversity influence the value of companies. The authors separately analyse the role of ecological considerations in corporate valuation in terms of growth, profitability, efficiency and risk factors.

Risks and risk management

Natural disasters are an inevitable part of life on Earth, and unfortunately, they occasionally also affect all societies and communities. Fortunately, human ingenuity can often successfully reduce the occurrence and impact of unexpected events with the help of impressive engineering solutions. However, it should be noted that in many cases, nature does the same thing for us! Mangrove forests and coral reefs protect coastal areas from storms and waves, tree roots and natural vegetation prevent landslides and avalanches, and beavers build dams to protect against flooding of smaller streams and rivers, which are subject to the greatest fluctuations. Beyond natural disasters, ecosystems mitigate the effects of environmental variability on a daily basis, thereby smoothing out the volatility of yields from nature-related economic activities.

However, as biodiversity declines and ecosystems are destroyed, the risks increase. One area of research in biodiversity finance seeks, on the one hand, to assess and quantify these risks that nature poses to the economy. On the other hand, it also examines the opposite effects: what risks do the activities of an economic entity pose to nature, and how can the extent of these risks be avoided or reduced? Understanding this is crucial for company managers, as well as for investors and decision-makers.

The study by *Khandelwal* and *Khandelwal* (pp. 9–31) contributes to the former line of research, examining the effects of biodiversity loss on the stability of the financial sector. By synthesising the literature on the subject, the authors demonstrate that biodiversity loss is closely linked to credit, market, operational, reputational and regulatory risks, and they explore the financial mechanisms through which these effects are transmitted.

In their study, *Taddei* and *Ielasi* (pp. 153–173) provide a comprehensive overview of the regulatory frameworks related to biodiversity and environmental risks, focusing on the guidelines of the *Corporate Sustainability Reporting Directive* (*CSRD*) and the *European Sustainability Reporting Standards* (*ESRS*), concluding their work with a summary of the literature on metrics related to biodiversity risks.

Dallagiacoma and *Torelli* examine (pp. 175–201) how the European Union encourages companies to integrate biodiversity protection into different levels of their operations. In their study, they pay particular attention to the main provisions

of the recently adopted Nature Restoration Law and the Corporate Sustainability Due Diligence Directive, highlighting their expected impact on corporate practices.

Financial products and methods

Comments on biodiversity are still rare in the reports of publicly traded companies, and their level of detail varies greatly. Traditional financial products have limited ability to direct capital towards projects that support biodiversity. Since investor activism, corporate reputation and well-understood business interests together are still insufficient, innovative financial products are needed to attract capital aimed at financing nature-based and sustainable solutions with the right incentives. The approaches and tools outlined in the following three studies paint an encouraging picture of the possibilities.

Naffa introduces (pp. 33–57) the concept of nature-inspired finance and points out that there are many parallels between the functioning of natural and financial systems, for example, in the areas of resilience, adaptation and regeneration. The author illustrates how these natural principles can be applied in the development of investment portfolios and the design of financial products and then reviews the financial instruments and methods currently used to finance biodiversity.

Agliardi and *Agliardi* point out (pp. 205–232) that the analysis of biodiversity-related financial instruments has focused heavily on the examination of stock returns, while the examination of other relevant financial products has so far been neglected. In their study, they present biodiversity-related sustainability-linked bonds (BrSLBs), whose coupon payments are made only if predefined performance indicators are achieved. The authors are the first to develop a comprehensive pricing model for BrSLBs, which pose a complex financial mathematical problem due to the embedded optionality of the bonds.

Arjaliès, Bernard and *Patel* contribute further to the literature on biodiversity-linked financial products in their study (pp. 233–266) by outlining the characteristics and methodology of biodiversity offsets and lending and then making recommendations for overcoming the shortcomings of these products.

Recommendation

Due to their interdisciplinary nature, I highly recommend the studies outlined above to researchers in both scientific fields. The works in this volume and the literature they reference cover most of the important publications on biodiversity financing to date.

The final chapter of the book, based on *Saba's* work, may serve as a starting point for planning future research, as it outlines current research trends in biodiversity finance and future opportunities based on gaps and shortcomings in the literature.

The book may also be useful reading for practicing financial professionals and investors working at funds or companies dealing with sustainability and ESG issues. On the one hand, the volume of biodiversity-related investments and investor demand are expected to grow in the future, and on the other hand, the strictness and scope of regulations on biodiversity and ecosystems may also be set to expand further.

Report on the 16th Annual Financial Markets and Liquidity Conference*

Zsuzsa R. Huszár – Soma Csaba Lehotzky

1. Conference overview and opening ceremony

The 16th Annual Financial Market Liquidity Conference (AFML) was held in Hungary from 15 to 17 October 2025 and marked a significant milestone in the event's history. The meeting featured over 200 participants from 40 countries, affirming its status as a premier international platform for advancing cutting-edge research in financial markets and their broader societal implications. The AFML Conference was jointly organised by the Institute of Finance (IoF) at Corvinus University of Budapest (CUB), the Game Theory Research Group at ELTE Centre for Economic and Regional Studies, the Faculty of Economics at Eötvös Loránd University, and the Department of Finance at ESSEC Business School (under the CY Initiative of Excellence).

This year's edition was substantially larger and broader in terms of thematic coverage compared to previous years, expanding the legacy topics of game theory, financial economics, and mainstream finance topics (e.g. corporate finance, investment, asset pricing, and banking) to include Artificial Intelligence (AI) and machine learning, sustainable finance, household finance, and alternative investments such as crypto and tokenomics. Whereas earlier conferences typically lasted 1.5 to 2 days, the 2025 conference was extended to 2.5 days to create more space for meaningful academic and industry interaction.

To foster deeper collaboration, the conference opened with a half-day programme dedicated to informal engagement, featuring an editorial panel discussion followed by topic-based breakout sessions. This opening afternoon was designed to give participants an opportunity to connect even before the main sessions began, strengthening the sense of community and facilitating early-stage feedback on research ideas. The two full days that followed offered a rich schedule of parallel sessions, representing the most extensive programme the conference had ever hosted.

* 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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This year, there were four parallel sections, more than in any previous edition. Three parallel sections featured full-length paper presentations across key topics in financial market liquidity. The fourth section was devoted to short-format "speed talk" presentations, tailored specifically for PhD students, early-career researchers, and young academics. These sessions offered fast-paced interactions with journal editors and senior scholars. Throughout the event, participants also had access to a designated discussion room, available at all times for small-group meetings, networking, and extended research conversations beyond the formal programme.[1]

One distinctive feature of the 2025 conference was the level of editorial engagement. Each session – across all of the sections – had two editors assigned, ensuring that participants received extensive, high-quality feedback on their work. This structure made the conference an exceptional platform for early-stage research development and strengthening ties between academics and the editorial community.

Overall, the expanded format, broader topical coverage, and emphasis on structured and informal interactions made the 2025 edition of the AFML conference the most dynamic and inclusive to date.

2. Pre-conference events: 15 October 2025

Official proceedings began late afternoon of 15 October 2025, following registration and a welcome reception. This was immediately followed by the Welcome Dinner, Editorial Panel discussion, and Networking Session with a wine reception.

The evening's central feature was an Editorial Plenary Session at 7 PM, featuring four distinguished current and former journal chief editors: *Luitgard Veraart* from London School of Economics and Political Science (UK), *Andrea Vedolin* from Boston University Questrom School of Business (USA), *Jeffrey Pontiff* from Boston College (USA), and *Robert Faff* from Bond University (Australia) and Corvinus University of Budapest. These editors represented a wide disciplinary range, covering expertise from mathematical finance to traditional corporate finance, investment topics, and alternative finance.

Luitgard Veraart works in financial mathematics and statistics in finance, as the Associate Editor of Applied Mathematical Finance, Mathematical Finance, and the SIAM Journal on Financial Mathematics and Operations Research. *Andrea Vedolin*, with a strong focus on theoretical asset pricing at the heart of the finance discipline, has a strong editorial presence as Associate Editor of several top finance journals, including the Journal of Financial Econometrics, the Review of Financial Studies,

[1] https://www.uni-corvinus.hu/ind/afml-conference/?lang=en#accordion-item-1001

the Journal of Finance, and the Review of Asset Pricing Studies. Jeffrey Pontiff is an experienced editor, having long served as the executive editor of the Review of Asset Pricing Studies and now as associate editor at the *Journal of Financial and Quantitative Analysis*, *Financial Management*, and the *Journal of Wine Economics*. The 5th invited editor, *Simona Mateut* from Nottingham University, the Editor-in-Chief for the Journal of Multinational Financial Management, Associate Editor for the Journal of Climate Finance, and a member of the Editorial Review Board for Small Business Economics, was not able make it to the editorial session but was an active participant at the conference, chairing the sustainable finance special session.

The panel offered candid, insightful guidance to young researchers on the most promising and, conversely, the most saturated research areas. Notably, the panel exhibited a split consensus on key research directions: while some editors advocated exploring rising new topics related to AI and Machine Learning (ML), two editors strongly suggested that researchers focus on first-order investment preferences and core risk questions, and explicitly recommended avoiding sustainable finance topics for maximising novelty and impact in top-tier publications.

Following this plenary session, four concurrent, specialised *Fireside Chat Sessions* provided further opportunities for networking and topic-specific engagement across the themes of AI and machine learning, mathematical finance and game theory, household finance, and sustainable finance.

3. Day one sessions (16 October)

The conference was formally opened by *Péter Csóka*, who introduced the Rector of the Corvinus University of Budapest *Bruno van Pottelsberghe*, who shared the new strategic vision with the audience. Following this introduction, *Zsuzsa R. Huszar* introduced the first Keynote speaker, *Jeffrey Pontiff*, who presented his research entitled, "A Century of Market Reversals: Resurrecting Volatility". His work highlighted the strong role of volatility, rather than volume, in driving autocorrelation and reversal of market returns, supporting the construction of a more robust, volatility-based liquidity risk factor.

In line with the title of conference, *Pontiff* chose financial market liquidity as the subject of the keynote address. Liquidity has long been recognised as a critical determinant of asset prices and expected returns. Theoretical models such as *Ho* and *Stoll* (*1981*) and *Grossman* and *Miller* (*1988*) posit that risk-averse liquidity providers demand compensation for absorbing order imbalances, causing short-term return reversals. Empirical work by *Campbell, Grossman,* and *Wang* (*1993*) and *Conrad, et al.* (*1994*) documents links between trading volume and return autocorrelation, inspiring *Pástor* and *Stambaugh* (*2003*) to introduce a market-

wide liquidity risk factor based on volume-induced reversals. Despite its conceptual appeal, the Pástor–Stambaugh factor has not achieved widespread adoption in practice or academia, partly due to its instability and sensitivity to specification choices (*Pontiff* and *Singla 2020*).

Based on a current working paper, "A Century of Market Reversals: Resurrecting Volatility" by *Bogousslavsky, LeBaron* and *Pontiff*, the presentation revisited the foundations of liquidity pricing using nearly a century of high-frequency Dow Jones intraday data (1933–2023). The authors argued that prior literature underemphasised volatility – a core component of inventory risk – because volatility was latent and difficult to measure precisely. The authors provided a high-powered test of inventory models: by leveraging realised volatility estimates from intraday returns, they reduced measurement error by over 86 per cent compared to daily GARCH-based estimates.

Key Contributions:

Volatility as the dominant driver of reversals: Across all subsamples, return autocorrelation is strongly and negatively related to anticipated volatility, while the effect of volume is weaker and inconsistent, significant only in certain historical periods.

Anticipated vs. shock components: The authors disentangle expected volatility and volume from shocks using rolling-window forecasts (Corsi-type models). Negative autocorrelation is driven by anticipated volatility and anticipated volume, not by shocks.

Asymmetry and Collateral Constraints: Autocorrelations are lower following negative return days, consistent with tighter funding constraints for liquidity providers. This asymmetry persists for up to three trading days, reinforcing the role of margin and collateral in liquidity provision.

Liquidity Risk Factor Innovation: Extending *Pástor–Stambaugh* (*2003*), the authors construct a volatility-based liquidity risk factor by replacing volume with anticipated volatility. These factors are associated with a higher annualised long–short return (≈7.8 per cent vs. 3.8 per cent for PS), a higher Sharpe ratio, and greater robustness in comparison with the original volume-based factor. This suggests that volatility-based measures better capture systematic liquidity risk.

Overall, *Pontiff's* ongoing research challenges the traditional reliance on volume-based liquidity proxies and resurrects volatility as a central determinant of market reversals and liquidity risk pricing. By demonstrating that anticipated volatility, not just shocks, contributes to liquidity provision, the paper offers a more theoretically coherent and empirically robust framework for asset pricing models incorporating liquidity risk.

3.1. Day one academic sessions and research highlights

The morning sessions featured a Special Session on Mathematical Finance and Game Theory alongside sessions on Asset Pricing, Corporate Finance.

The Special Session on Mathematical Finance and Game Theory, chaired by *Péter Csóka*, explored rigorous quantitative methods to model systemic risk, institutional stability, and competitive outcomes in finance. The session featured papers that developed novel frameworks for analysing complex interdependencies. *Luitgard Veraart* introduced a modelling framework for contagion in financial networks, demonstrating how interacting channels, such as funding withdrawals and price-mediated fire sales, can trigger systemic crises, with the extent of risk highly sensitive to participants' withdrawal strategies. Meanwhile, *Tamás Solymosi* presented a theoretical framework with three enterprise games, constructively proving that the core is non-empty under specific constraints of a rooted tree hierarchy, modelling cooperation issues constrained by access to a vital resource. Focusing on regulation and data, *Barbara Dömötör* addressed the practical challenge of estimating Through-the-Cycle Default Probabilities (PDs) for Internal Ratings-Based (IRB) models, offering a method for simultaneous calibration across sub-portfolios that works even with incomplete data using the Basel single risk factor model. Finally, *Tamás Vadász* analysed the policy implications of data interoperability (Open Banking/Finance), highlighting a trade-off: sharing customer data improves competition in credit services, but may increase prices in data-generating services such as payments.

The session Flash Talk I. Mathematical Finance and Machine Learning (co-chaired by *András Fülöp* and *Robert Faff*) showcased an impressive spectrum of methodological innovation at the intersection of mathematical finance and AI. The presentations ranged from rigorous theoretical work on network connectedness and copulas to machine learning applications in volatility forecasting and risk mapping across developed and emerging markets. It was particularly interesting how many speakers struck a healthy balance between theoretical depth and empirical demonstration – exactly what a flash-talk format rewards. The energy in the room was palpable, and the concise structure encouraged clear, purposeful storytelling of complex ideas. Overall, this session set a high bar for clarity, discipline, and cross-fertilisation between traditional quantitative finance and modern data-driven techniques.

The afternoon programme included two Special Sessions: Household Finance (chaired by *Zsuzsa R. Huszár*) and Flash Talk II: Banking and Regulation (co-chaired by *Robert Faff* and *Tamás Vadász*). The first session opened with a short presentation on gendered patterns in Hungarian households' financial decision-making and their implications for household investment and wealth, followed by talks by two prestigious household finance experts, *Laurent Bach* from ESSEC Business School and *Sofie R. Waltl* from the University of Cambridge. Using unique

Swedish microdata, Laurent Bach examined individual-level profitability of housing investments and found that, when accounting for all construction, furnishing, and related costs, real estate investments are generally less profitable for women; the material gain is concentrated among male investors who undertake major renovations themselves. Overall, the findings challenge the widespread belief that real estate investment consistently delivers substantial positive returns. The final presentation by Sofie Waltl was policy-charged, addressing the omission of owner-occupied housing (OOH) from the Harmonised Index of Consumer Prices (HICP), which is likely to have resulted in limitations in the European Central Bank's (ECB) inflation measurement framework. Addressing the concern that excluding OOH can lead to systematic biases in monetary policy decisions, the authors show that a suggested revised inflation measure would have signalled inflationary pressures earlier during the Covid-19 pandemic, thereby enabling more timely policy response. The findings underscore the importance of revisiting the methodological foundations of inflation measurement to mitigate risks of policy overshooting and enhance macroeconomic resilience.

The latter session was notable for its focus on acute policy concerns, such as the credibility of bail-in regulation in EU banks' bond issuance, and an empirical study of "Systemic Risk and Climate Change" in the Polish banking sector. The papers addressed an array of timely theme, such as bail-in credibility, capital requirements, climate-related systemic risk, and the strategic dynamics of liquidity provision. What stood out was the clear policy relevance of these contributions and their grounding in high-quality empirical work, often using European datasets. Presenters handled the time discipline of the flash format admirably, articulating their research questions and findings with economy and focus. The ensuing discussion was rich and collegial, reflecting AFML's culture of constructive critique and intellectual curiosity.

The day concluded with Flash Talk III: Macro Policy and Household Finance (co-chaired by *Robert Faff* and *Laurent Bach*). The "pitches" in this session – spanning topics from digital currency implications and monetary policy transmission to taxation, workforce exposure to AI, and behavioural aspects of household decision-making – demonstrated both creativity and relevance. Many of the early-career presenters demonstrated an impressive command of the pitching mindset: sharp framing, credible motivation, and clear articulation of their contribution. The breadth of macro-household linkages explored was especially refreshing, underscoring how sound empirical design can yield meaningful policy insights. The enthusiasm and preparedness of the speakers made this an enjoyable and genuinely inspiring session – an excellent example of how concise, well-crafted research pitches can energise an audience and stimulate broader collaboration.

4. Day two sessions (17 October)

The second day opened with the keynote address delivered by *Andrea Vedolin* (Boston University) on "Expectations in Asset Pricing". The session was chaired by *Helena Naffa*.

The second keynote presentation, entitled "Subjective Beliefs in Asset Pricing", by *Andrea Vedolin* from Boston University, focused on investors' heterogeneity. The presenter started with some slides of local relevance, discussing Hungarian forint and euro relation, highlighting the high dispersion of future expectations of this currency pair among market participants. The presentations building on her current research (*Crescini et al. 2025*; *Molavi et al. 2025*) explored the critical role of subjective beliefs in determining asset prices and challenged the dominant paradigm of Full Information Rational Expectations (FIRE). Traditional asset pricing models assume that investors have complete knowledge of the economy's structure, shocks and probabilities, leading to homogeneous expectations. However, this assumption is often unrealistic because information is dispersed, agents may not be Bayesian, and models can be misspecified. While the Recovery Theorem (*Ross 2015*) established the theoretical possibility of disentangling risk aversion from natural probabilities using option prices, empirical applications often struggle with the 'representative agent' assumption. Vedolin and her coauthors extend this foundation by allowing for the recovery of heterogeneous subjective beliefs. The presentation, while emphasising that asset prices are forward-looking and depend on investors' subjective expectations, reviewed empirical evidence showing systematic forecast errors, underreaction, and overreaction in expectations (*Coibion – Gorodnichenko 2015*), which contradict FIRE.

Vedolin highlighted the "wilderness" of alternative models of expectation formation, including rational inattention, sticky information, higher-order uncertainty, cognitive discounting, and behavioural biases such as overconfidence and representativeness. To address these challenges, the presentation advocated for approaches that either assume empirically grounded models of belief formation ("bottom-up") or treat expectations as primitives observed in data ("top-down"), leading to temporary equilibrium frameworks. One concrete application is provided through the term structure of interest rates, where the expectation hypothesis traditionally links long-term yields to averages of expected short rates under rational expectations (*Molavi et al. 2025*). Vedolin demonstrates that without imposing FIRE, one can still characterise relationships between yields and beliefs and test for time-varying risk premia using survey and price data. The analysis reveals that expectations across maturities are often inconsistent with temporary equilibrium relationships, especially at long horizons, suggesting that risk premia are not constant and that subjective beliefs significantly shape yield curve dynamics. The conclusion

underscores the importance of incorporating subjective expectations into asset pricing models and leveraging new data sources, including surveys and market prices, to better understand belief heterogeneity and its implications for financial markets.

4.1. Day two academic sessions and research highlights

Following the second keynote, the morning included the Special Session: AI & Machine Learning (chaired by *András Fülöp*), confirming the conference's commitment to computational finance.

Flash Talk IV: ESG and Sustainable Finance (co-chaired by *Simona Mateut* and *James Steeley*) covered a wide range of papers exploring climate risk measures and the impact of natural disasters. Highlights included the development of "A Greenwashing Index" and an analysis of "Credit Supply and Decarbonisation" in the euro area.

The final sessions featured the Special Session: Climate Finance, chaired by *Helena Naffa*, and concluded the formal academic programme. The session's first presenter was *Simona Mateut*, who, as an Editor-in-Chief of *Multinational Financial Management* and an editor at *Climate Finance*, provided valuable context while presenting her research on Indian firms' reaction to mandatory Corporate Social Responsibility (CSR) spending and stock price crash risk. This was followed by a presentation by *PhD student Xinglin Li* from Helena Naffa's Sustainable Finance Research Center, on the relationship between Biodiversity, Physical and Transition Risk, and firm financial performance. The session concluded with *Milena Petrova*'s work focusing on a sustainable/resilient portfolio approach within US real estate firms.

5. Concluding remarks

The 16th AFML Conference was a resounding success, distinguished by the depth and breadth of the research presented. The event provided a unique opportunity for participants to discuss the latest research methods, exchange ideas on current topics, and strengthen global research networks, particularly in emerging areas such as AI-driven finance and climate risk. The Organising Committee gratefully acknowledges the support of the sponsors, including the Scientific Mecenatúra Grant of the National Research, Development and Innovation Office, KELER CCP, and Morgan Stanley.

The conference concluded with a brief farewell reception held in the Main Building Courtyard and a final visit to the University's museum, which proudly displays a large sculpture of Karl Marx, recalling the institution's historical namesake before its current designation as the Corvinus University of Budapest.

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Report on the 5th International Conference "Digital Transformation and Sustainability in Global Financial Economics"*

Tim A. Herberger – Manuela Ender – Michael Kuttner

On 25 September 2025, the 5th edition of the conference "Digital Transformation and Sustainability in Global Financial Economics" was held at Andrássy University Budapest, marking this institution's 5th anniversary. The conference also received financial support from Bosch Hungary for the first time. About 50 experts (mainly from Austria, Germany, Hungary, and Switzerland) presented and discussed the latest findings on digitalisation and sustainability in finance. A total of 19 research projects were presented, organised into six sessions. Each presentation was followed by a discussion, which kept the conference lively and open to constructive feedback from the audience. Two keynote speeches were also highlights of the conference.

1. Initial situation

The rapid advance of digitalisation poses profound strategic, operational and organisational challenges for a company's finance, management accounting, and financial accounting functions. Digital transformation requires organisations to shift from traditional, often linear, and document-centric processes to integrated data-driven architectures supported by automation, analytics, and platform technologies. In the finance domain, automation through robotic process automation (RPA), artificial intelligence (AI), cloud-based enterprise systems, and platform economies are reshaping core transactional activities such as bookkeeping, financial reporting and compliance monitoring. While these technologies create significant efficiency gains, reduce transaction costs and minimise manual errors, they also increase dependencies on high-quality data, interoperable IT infrastructure, and robust governance mechanisms (*Davenport – Ronanki 2018*). Digital transformation is associated with a shift from retrospective variance analysis to forward-looking strategic decision support. Advanced analytics and machine learning enable

* 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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predictive forecasting, scenario modelling, and continuous performance monitoring. This transition redefines the management accountant's role from report producers to proactive business partners, requiring analytical literacy, data governance expertise, and strong cross-functional collaboration skills (*Moll – Yigitbasioglu 2019*). However, the integration of algorithmic decision tools raises challenges related to model transparency, bias mitigation, and the appropriate division of tasks between human judgment and automated insights. Ensuring explainability and accountability is essential for managerial trust and the effective use of digital tools. Accounting functions face their own set of transformation pressures. The rise of real-time data processing, digital invoices, distributed ledger technologies such as blockchain, and globally connected cloud platforms have opened up new opportunities for the transparency, traceability, and auditability of financial information. However, these developments also heighten exposure to cybersecurity threats, increase the complexity of compliance with international reporting standards, and require continuous updates to internal control systems (*Yermack 2017*). Additionally, auditors and accountants must adapt to new forms of digital evidence and automated audit trails, challenging traditional assurance procedures, and professional skill profiles.

Across all three areas – finance, management accounting, and financial accounting – digitalisation is not solely a technological challenge, but also a cultural and organisational one. Successful transformation requires substantial investments in digital capabilities, workforce reskilling, and change management. Employees must be prepared to interact with data-driven systems, interpret analytical outputs, and contribute to the iterative process redesign. Leadership commitment and a clearly articulated digital strategy are critical for aligning systems, competencies, and governance structures (*Brynjolfsson – McAfee 2014*). Moreover, organisations must balance innovation with risk management to ensure that the adoption of emerging technologies does not undermine data integrity, ethical standards, or regulatory compliance.

Market requirements, including the expectations of market players and regulations, place similarly complex and challenging demands on the triad of finance, management accounting, and financial accounting in terms of companies' sustainability efforts and their communication. Regulatory pressure, stakeholder expectations, and global frameworks – such as the EU Corporate Sustainability Reporting Directive (CSRD) and Task Force on Climate-related Financial Disclosures (TCFD) – compel firms to integrate environmental, social, and governance (ESG) considerations into core decision-making. However, this integration brings substantial methodological, organisational, and strategic challenges. In finance, sustainability activities require the alignment of capital allocation and investment decisions with long-term ESG risks and opportunities. Traditional financial models

often struggle to incorporate non-financial externalities, uncertain climate scenarios, and long-term societal impacts (*Sullivan – Mackenzie 2006*). Financial managers must redesign valuation methodologies, adjust risk models, and justify investments whose returns may be less immediate but strategically essential. Additionally, sustainable finance instruments, such as green bonds, demand rigorous verification and risk assessments to avoid "greenwashing" concerns (*Flammer 2021*). The shift towards integrated performance management presents significant challenges for management accounting. Management accountants must establish systems capable of measuring and monitoring ESG performance indicators that are heterogeneous, partly qualitative, and lack global standardisation. Integration of sustainability metrics into planning, budgeting, and incentive systems requires new data governance structures, interdisciplinary collaboration, and the ability to reconcile potential conflicts between short-term financial targets and long-term sustainability goals. This makes management accounting more complex and increases reliance on cross-functional expertise. Accounting, perhaps, faces the most profound transformation. Sustainability reporting has evolved from voluntary disclosure to regulated assurance-relevant reporting. However, ESG data often suffer from limited reliability, inconsistent measurement methodologies, and fragmented reporting frameworks (*Kotsantonis – Serafeim 2019*). Accountants must address challenges related to data quality, internal control systems for non-financial information, and the need for assurance of sustainability statements. The incorporation of climate-related risks, such as impairment testing or provisioning, into financial statements adds additional technical complexity.

Similar to the previous four conferences on Digital Transformation and Sustainability in Global Financial Economics (*Ender et al. 2025*; *Herberger – Kuttner 2024*; *Herberger 2023*; *Herberger 2022*), many participants from research, teaching, and business practice gathered at the fifth anniversary conference at Andrássy University Budapest to exchange ideas on these challenges and critically discuss possible solutions to specific problems in the finance, management accounting, and financial accounting industry.

2. Summary of the presentations of the conference

The first keynote, delivered by industry expert *Galina Biel*, Director Operations Accounting and Controlling GS Hungary, Serbia, Slovenia, and Croatia at Robert Bosch Kft, offered a comprehensive look at the digital transformation journey of a global industrial company. Biel highlighted key technologies, including process automation through RPA, machine learning-based forecasting tools, cloud platforms for real-time reporting, and intelligent workflow systems. A core theme of her presentation was the need to standardise global financial processes. In a group with numerous national subsidiaries, one of the biggest challenges was harmonising

different data structures, system landscapes, and compliance requirements. Biel illustrated how Bosch had established uniform process models and eliminated redundant workflows through digital initiatives – an essential step in realising economies of scale and increasing transparency. Another focus is on personnel and skill change. Biel emphasised that digital transformation went far beyond technological renewal. What was needed was the cultural realignment of the entire finance organisation: management accountants had to increasingly develop analytical, technological, and communication skills. The roles were changing from number-oriented "scorers" to data-driven business partners who supported strategic decision-making. Biel's reflection on change management was particularly valuable: Digital transformation could only succeed if employees were actively involved, trained, and supported in their willingness to learn. Several contributions throughout the remainder of the conference scientifically substantiated this human factor.

The first scientific session examined digital innovations and their diffusion in finance and management accounting departments. *Felix Fischer* and *Michael Kuttner* (Salzburg University of Applied Sciences) analysed factors that promoted and inhibited the spread of digital concepts in finance functions. Their systematic approach showed that technological possibilities alone were not enough: organisational commitment, data quality, and internal champions were crucial. *Faris Getzin* (HTW Berlin), *Thomas Henschel* (HTW Berlin), *Michael Kuttner*, and *Earl McKinney* (Bowling Green State University, USA) discussed the role of institutional constraints on AI adoption in SMEs and derived the reform needs for management accounting. *Luca Hüvel* and *Alexander Bull* (IU International University) presented an AI-supported management accounting system that realised efficiency gains in a shared service centre. Their paper discussed concrete use cases for algorithmic decision support. *Maximilian Gill* (University Witten/Herdecke) examined the monetary mechanisms of Ethereum. His analysis illustrated how blockchain protocols created incentive systems with economic and regulatory implications.

In a parallel session that focused on sustainability reporting and regulatory challenges, *Ute Laun*, *Melanie Fürch*, and *Manuel Gesslein* (HSLU Lucerne) provided an overview of the developments in ESG reporting. *Julius Jensen* (Andrássy University Budapest) examined the influence of tax transparency through country-by-country reporting on profit shifting in multinational companies. *Manuela Ender* (IU International University) discussed the tension between circular economy and Solvency II risk reports in the insurance sector. *Jens Müller-Merbach* (Frankfurt University of Applied Sciences) critically analysed the usefulness of ESG indices against the backdrop of methodological challenges and potential distortions. This session demonstrated how complex sustainability reporting remained due to regulatory fragmentation and a lack of standardisation.

The banking sector was caught between regulation, sustainability, and changing customer expectations. This development was discussed in the first afternoon session by *Yanik Bröhl* and *Arnd Wiedemann* (University of Siegen). *Lukas Bauer* and *Florian Follert* (Private University Schloss Seeburg) analysed the "decoupling" of Austrian banks between the aspirations and reality of European environmental regulation. *Tatiana Nikitina* and *Maria Skalaban* (St. Petersburg State University of Economics) showed how savings behaviour could contribute to stability and sustainable capital allocation in households. *Florian Perst* (IU International University) examined the gaps between the digital customer journey and customer expectations in the German banking industry. The session highlighted that banks had to simultaneously navigate digital, regulatory, and environmental transformation paths.

In another afternoon session on the topic of "Shaping Competitiveness" the focus broadened to include economic resilience and business model innovation: *Maximilan Gill* and *Marcel Tyrell* (Witten/Herdecke University) analysed the financial effects of collective reputation in German quality winegrowing. *Andreas Höhn* and *Tim Herberger* (Andrássy University) examined urban vulnerabilities and business model transformations in city centres. Finally, *Karl Hanke* (Andrássy University) shed light on tenders in civil engineering involving digital Building Information Modeling (BIM) models.

In the early evening sessions, new financing methods and digital approaches to talent acquisition were presented and discussed in depth. *Jona Stinner*, *Marcel Tyrell,* and *Victor Wolff* (Witten/Herdecke University) examined private equity as a catalyst for corporate change and potential for value creation. *Moritz Baum*, *Jona Stinner,* and *Marcel Tyrell* analysed crowd investing signals in the context of subsequent venture capital financing and provided valuable insights into pricing mechanisms in venture capital markets. *Lisa Göpfert* (Andrássy University) presented a systematic literature review on digital and hybrid HR integration and the related developments and derived recommendations for different stakeholder groups. *Anke Reuter* (Andrássy University) provided an analysis of digital recruiting in SMEs and its potential to attract value-creating human capital activities. The last two presentations showed how critical digitalisation had become in dealing with the shortage of skilled workers.

The conference concluded with a second keynote speech that placed strong emphasis on theory and interdisciplinarity. *Christine Vallaster* (PLUS, Paris Lodron University Salzburg) analysed the dynamics of multi-sided digital platforms, for example, in the food industry, and showed how they were reconfiguring the institutional structures of all industries. Platforms included changing roles, power relations, information flows, and value creation logic. This had far-reaching implications. For finance: financial flows were recorded on a platform basis, in

a more granular manner and in real time; new valuation logics were emerging. Digital platforms generated new types of transaction data that challenged traditional accounting models; questions of data sovereignty, fair value measurement and automated documentation are coming to the fore. For management accounting: platforms enabled data-intensive AI-supported control mechanisms that rendered classic planning cycles obsolete. Vallaster showed that institutional change rarely occurred linearly. Platforms were rewiring entire industries, giving rise to new norms, roles, and governance structures. Her keynote speech combined technology economics theory, sustainability issues, and financial control mechanisms, opening up a transformative outlook for the future of finance.

The conference concluded with final remarks by *Tim Herberger* (Andrássy University Budapest), who summarised the day's key insights and emphasised the importance of continued dialogue and innovation at the intersection of digital transformation and sustainability in the finance sector, as well as across other disciplines in business administration and economics. The 5th Conference provided a valuable platform for discussing critical issues, from ESG performance to technological innovation in finance, management accounting, and financial accounting, inspiring participants to continue their research projects.

3. Concluding remarks and outlook

The following four lessons learned were identified from the keynote speeches and individual research papers in various sessions after intensive discussions:

The importance of digitalisation, digital transformation and sustainability in creating corporate value and developing competitive advantages is largely undisputed. However, their specific definition and mode of action remain a highly dynamic field of research, with research findings that sometimes differ considerably.

Finance, management accounting, and financial accounting, and their connection to digital transformation and corporate sustainability efforts, also have significant spillover effects on other areas of business management, such as marketing, compliance, HR, and corporate communications.

The practical transfer and implementation of research results should be optimised and further harmonised through more intensive exchanges between theory and practice to increase effectiveness and efficiency gains in relation to digitisation and sustainability efforts in companies.

There are initial indications that efforts to digitalise and automate business processes and achieve a consolidated level of sustainability activities and efforts are increasingly being viewed by the market and its participants as hygiene factors in

the valuation of companies, and that it is becoming increasingly complex to realise concrete valuation advantages by pursuing sustainability goals and digitalisation objectives.

Finally, we would like to thank all the participants, especially the speakers, discussants, and administrative team behind the curtain. All of them contributed significantly to the success of the conference. We are particularly pleased that many young academics were represented at the conference. A conference anthology (*Ender et al. 2025*) for the 2024 conference was published in German in the fourth quarter of 2025 by Nomos Publishing and contains many of the papers presented at IU – Internationale Hochschule in Munich in 2024. A corresponding anthology is also planned for the 2025 conference, which will probably be published in the late summer of 2026 and will include many of the papers presented. The future of the conference is also secured: it is expected to take place on 21–22 September 2026, in Puch/Salzburg at Salzburg University of Applied Sciences. A call for papers will be published in early 2026.

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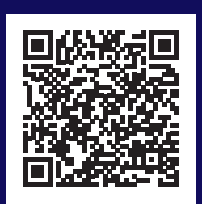

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