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Thesis synopsis

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Identification of systemically important financial institutions and their risk mitigation options in the European Union

PhD Dissertation

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Contents

1. INTRODUCTION

The global financial crisis has highlighted that the problems of financial institutions that are too large and too significant for the size of a country's economy and too complex can spill over into the financial system as a whole. Their bankruptcy could entail significant sacrifices in real economy as well as budgetary burdens. In order to avoid turbulences arising from this, economic decision-makers typically bail out systemically important institutions battling difficulties. However, it can be seen that this increases the moral hazard on the one hand, and drastically rises the budget deficit and public debt as a result of state recapitalisations and guarantees on the other.

In general, financial institutions[1] that can rely on public safety nets (Systemically Important Institutions – SII) because of their systemic importance may make systemically sub-optimal decisions in their profit maximisation because they do not take into account the negative systemic externalities that arise from their status. Dominantly because of the moral hazard caused by the implicit state guarantee, they may take excessive risks, which may also increase the likelihood of future problems. It is also worth looking at the issue from the perspective that the risks posed by systemically important financial institutions are relevant not only at the international level, but also in the European Union and the Central and Eastern European region. In Hungary and in the region, there are financial institutions whose individual institutional crises, due to their size or interconnectedness with other institutions, could undermine the stability of the financial system (in EU terminology, these institutions are called Other Systemically Important Institutions (O-SIIs)). At both the international and national levels, there is therefore a need to define as precisely as possible the scope of systemically important institutions and to identify the most effective ways to mitigate the risks associated with them in the future. In the dissertation, five main research questions related to the identification of systemically important institutions and their risk mitigation options are examined, focusing on the European Union banking systems. Our research questions are the following:

1) Is there a significant difference in the relationship between the systemic importance score for O-SIIs and the required O-SII capital buffer between the "new" and "old" or "northern" and "southern" groups of Member States in the European Union?

[1] In this paper, unless specifically indicated otherwise, typically the term systemically important financial institutions is used to refer to systemically important credit institutions, taking into account the essentially European focus.

2) How can the O-SIIs identified in the European Union be clustered according to the systemic importance scores defined by the EBA methodology?
3) Can a significant impact on the market value of O-SIIs at EU or regional level be identified in the case of official notifications made by the competent Member State or EU authorities?
4) Can a significant impact be identified on the market value of O-SIIs in the euro area as a result of the ECB's regulatory notification of a temporary capital buffer release in response to the coronavirus pandemic?
5) How is it possible to estimate the systemic risk allocation and additional capital buffers of Hungarian O-SIIs using Shapley value and how would such an allocation differ from the allocation under the current regulation?

In the EU regulatory framework, it is essentially at the national level that the national competent authorities set the levels of the additional capital buffers required for the first time for O-SIIs, and it is therefore relevant to ask whether differences in the capital buffer levels set by the authorities of each national group can be possibly identified, taking into account the systemic risk importance of each institution as well. The first research question seeks to answer this by grouping the EU Member States into "new" and "old" and "northern" and "southern" Member States. The division between "new" and "old" Member States basically refers to the countries that are supposedly less economically developed, having joined the EU since 2004, and those that have been members for a longer period of time and have a supposedly more developed economic and financial system. The division between "northern" and "southern" groups of Member States uses an approach that has been examined in the EU in several areas (e.g. fiscal discipline in Member States, possibly identifiable differences in labour productivity), i.e. the "southern" division considered less strict in the public eye and the "northern" division, which is often seen as more disciplined in policy terms. The EU financial services market can be considered a single market from a regulatory point of view, so if certain groups of Member States set the level of these capital buffers more strictly, or even less strictly, the extra capital cost of the additional capital buffer could put these financial institutions at an undue disadvantage or advantage. The issue is also relevant from a policy point of view, since if a significant difference can be identified in the setting of capital buffer rates between groups of Member States, this may justify the need for more detailed rules to ensure that O-SII capital buffer rates are set appropriately, ensuring a more uniform approach at EU level.

The second research question also focuses on examining possible heterogeneities in the O-SII issue, but not in the context of the competent authorities' decisions on the additional capital buffer rates for each group of Member States, but at the level of the identified O-SIIs. It basically seeks to answer the question to what extent the range of O-SIIs identified in the EU can be considered homogeneous. Although in principle the regulation of O-SIIs tries to treat these institutions in a uniform way, with a uniform set of instruments, typically through the use of a capital buffer requirement (there are of course differences in this regard, see the first research question), but it is worth examining the extent to which the group of O-SIIs can be considered homogeneous. To test this, we perform a cluster analysis to investigate the possible heterogeneity of O-SIIs. If, in fact, the examination of these institutions identifies a number of relatively distinct groups, then the need to fine-tune the current framework may also arise from a regulatory perspective.

In the context of the evolving regulatory framework for O-SIIs in the EU, an important question is how market participants react to public official notifications on O-SIIs following the regulatory identification of O-SIIs and how this affects the market value of the institutions concerned. The third and fourth research questions essentially examine this by focusing on the official notifications of the O-SII listings and the ECB's official notification of the temporary capital buffer release in the wake of the coronavirus epidemic. The public official notification of O-SII listings can have a negative impact on the one hand, as the O-SII range faces an additional capital buffer. Also, the O-SII nature may have the negative effect that the banks affected may face additional regulatory requirements that increase the bank's administrative and operational costs. Regarding the potential positive impact of official notifications on O-SIIs on the shareholder value, it is important to highlight that the state guarantee, that was implicit so far, becomes "explicit". Namely, the fact that the competent authority also declares that an institution is an O-SII effectively makes explicit the previous implicit state guarantee. Similarly to the case of the identification notifications, the impact of the ECB's notification of the temporary capital buffer release in the context of the coronavirus pandemic on the market value of the systemically important institutions of the affected authority is not clear. On the one hand, the notification may have the effect of being seen by investors as positive news, as more capital will be available for lending to the institutions concerned, but on the other hand, the notification is essentially about a temporary exemption, as with the lapse of the risks of the epidemic the capital buffers will have to be re-established, which may reinforce the negative effect. The identification of these impacts is also relevant from a policy point of view, as the research findings can be used to support policy-making mechanisms, since a more accurate assessment of potential impacts can improve the soundness and effectiveness of these decisions and avoid other unintended impacts.

The fifth research question essentially examines the feasibility of an alternative approach to the allocation of systemic risk and the determination of the additional capital buffers for O-SIIs in a given country's banking system, including the extent to which an alternative allocation of the systemic risk capital buffer would differ from the current regulatory allocation. Using the data of O-SIIs active in Hungary and determining the Shapley values of each institutions, a possible alternative practical approach is presented for the systemic risk allocation and the determination of the additional capital buffers of O-SIIs. Our approach, based mainly on the research of *Tarashev et al. (2015)*, may be relevant from a policy perspective because of several potential beneficial features. On the one hand, this methodology could, with certain simplifications, be suitable to apply a quasi market information methodology to banking systems in countries where high-frequency stock market data are not available for the institutions concerned. On the other hand, this approach can also be applied to relatively low levels of direct interconnectedness, even with low interbank lending or swap exposures. In such cases, the main challenge in defining systemic risk is that the direct "contagion" effect is relatively low due to low direct network exposures, making it more difficult to define the interconnectedness dimension using them. With our approach, the indirect interconnectedness effects, such as network importance due to indirect, asset price correlations, can also be partially taken into account. From a policy perspective, it could be a potential area of application as a complement to the indicator-based EBA methodology currently required by the regulation, both in terms of systemic risk importance and in the definition of additional capital buffers.

2. IDENTIFYING SYSTEMICALLY IMPORTANT INSTITUTIONS AND MEASURING THEIR RISKS

The importance of Systemically Important Financial Institutions (SIFIs) was put into the spotlight by the 2008 financial crisis. The outbreak of the crisis highlighted the systemic importance of the situation and had significant social and economic repercussions (*BCBS, 2012; BCBS, 2013*):

- The financial distress and potential failure of a major institution can place a heavy burden on the international financial system as a whole, but similarly the stability of national financial systems can also be threatened by the failure of a locally significant financial institution;

- it may jeopardise the activity of real economy through the bankruptcy of a major institution, and temporary or permanent disruption of financing channels may lead to significant losses in the real economy, with all the social consequences that entails (e.g. significant unemployment, evictions of debtors who are unable to pay their loans);
- the recapitalisation of major financial institutions to ensure the continued functioning of critical financial functions could place a heavy burden on public finances and hence taxpayers.

The theoretical framework for the identification of systemically important financial institutions is currently not fully crystallised in the literature. The most common approaches can basically be divided into two main groups. One approach essentially defines systemically important financial institutions based on their contribution to systemic risk. According to the other approach, the real determining factor is the extent to which an institution would be affected by a systemically significant event and the impact on other stakeholders *(Weistoffer, 2011; Drehmann–Tarashev, 2011, BCBS, 2012; BCBS, 2013).*

The number of studies related to the identification and risk measurement of systemically important financial institutions has grown dynamically in recent years. Three main directions are starting to emerge in the literature: (i) methods based on market information, (ii) indicator-based methods and (iii) network methods. *Weistoffer (2011)* already distinguished the first two directions earlier, but he did not treat network methods as a separate field. In the following, these measurement methods are reviewed briefly.

2.1. Methods based on market information

The methods based on market information typically translate the risk measurement concept of credit institutions and investment activities into a systemic risk framework. A general feature of the methods based on market information is that they typically use high-frequency data (e.g. CDS spreads, risk premia on uninsured liabilities, return on equity, etc.). The advantage of these methods is that, on the one hand, their data requirements and data collection costs are not significant, since they work with generally available market data, and on the other hand, thanks to high-frequency data, they can capture, at least in theory, even the daily evolution of changes in systemic importance (see, for example *Brownless–Engle, 2010; Huang et al., 2010*). One drawback of these methods is that these high-frequency data are not available for many institutions, or the trading of the relevant products (e.g. CDS markets) is not sufficiently deep, so the regional and domestic applicability of this approach, for example, is severely limited.

The CoVaR indicator[2] of *Adrian–Brunnermeier (2008)* uses a Value at Risk (VaR) calculation at the banking system level assuming a crisis of a financial institution under study. By characterising the tails of the joint return distributions, the CoVaR methodology moves from the extreme risk of an individual institution to the expected joint risks of the system under stress, taking into account negative, indirect, spill-over and contagion effects created at the systemic level. In the course of application, the difference ΔCoVaR is the difference between the lower quantile of order p of the asset return defined for the financial system as a whole, assuming a crisis of the individual institution under consideration (i.e. that the individual asset return reaches the assumed extreme loss-making performance of the lower quantile) and the lower quantile of the asset return of the system (i.e. the assumed extreme loss-making performance of the system), assuming the median asset return of the individual institution under consideration. Thus, ΔCoVaR represents the marginal contribution of an individual institution to systemic risk (see also *Castro-Ferrari, 2014*).

As another representative of the methods that use market information, *Acharya et al. (2017)* defined a so-called marginal expected shortfall (MES) indicator that estimates the expected shortfall/loss of a given institution under the assumption that the loss of the banking system is not below (in absolute value equal to or greater than) the lower quantile of order p of the system's return distribution (weighted average return distribution), i.e. the VaR. In the case of MES, the expected loss of an individual bank is therefore examined in the period when the system has an extreme loss-making performance, whereas in the case of CoVaR, the expected loss of the system is determined in the case of an extreme loss-making performance of the individual institution. The MES is interpreted by the authors as the marginal contribution of the institution under study to the systemic loss. For the interpretation embedded in the MES model, the so-called systemic expected shortfall (SES) indicator can also be defined. SES measures the expected contribution of an individual bank to the external economic costs of being capitalised below the target level, assuming that the system is capitalised below the target level. As a factor of the expected social cost expressed by SES, the SRISK *(Brownless–Engle, 2010)* appears, which measures the expected shortfall of the capital adequacy of the bank under study from a

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[2] In the CoVaR indicator, which is conceptually closer to a conditional VaR estimate, the prefix "Co" is intended by the authors to be an abbreviation of the "conditional, contagion, comovement" characteristics referring to the systemic approach.

bank-specific target level, assuming that the capital adequacy of the system is below a system-wide target level.

Finally, among the methods using market information, the approach of *Drehmann–Tarashev (2011)* is also worth mentioning. According to *Drehmann – Tarashev (2011)*, previous ES measures defined under the assumption of systemic losses are limited in their ability to capture the systemic importance of an institution. In fact, the measures they call participation approach (PA) do not take into account the fact that an institution, because of the risks, transmitted through its network of banking and interbank relationships, may be highly significant even if its individual losses during a crisis are less significant at the systemic level. In contrast, the contribution approach (CA) proposed by the authors identifies the risk of an institution not only with the losses incurred by the real economic agents providing funds for the bank. Instead, the systemic risk of an interbank intermediary institution will be increased if it on-lends interbank funds originating from other credit institutions to credit institutions (or real economy agents) with high conditional expected losses (see also *Weistoffer, 2011*). The authors propose to use the Shapley value concept of cooperative game theory to measure risk allocation on a contribution basis. Accordingly, the network of connections of the banking system under study can be decomposed into various combinations of possible subnetworks. The risk measure for a surveyed institution is obtained by determining the average systemic ES increment after adding the surveyed institution to various combinations of sub-networks.

2.2. Indicator-based methods

An important advantage of the indicator-based methods based on the data of supervisory reporting is that they are easy to communicate, transparent, easy to interpret and simple to use for rule-making. Accordingly, the identification methods in international and EU recommendations are typically based on these. Indicator-based metrics using supervisory reporting data can cover a wide range of critical functions and negative externalities. In most cases, this is done by weighting institutions' size, critical economic functions (lending to real economy agents, deposit taking, interbank intermediation, operation of financial infrastructure, etc.) and activities involving contagion risk (high activity in complex financial product markets, stock of cross-border transactions) by market share in a single indicator. Hence, this type of measurement is often referred to as a share-based method. The methodology also handles well when market shares need to be defined in different units (e.g. loan portfolio in monetary terms, number of transactions in payment systems, number of customers with depositors or number of branches) or when there is a need to aggregate variables for which the concept of market shares is less well understood (e.g. centrality indicators for network studies, ratios describing the funding structure). An additional advantage of the methodology is that it can be generally applied to OTC institutions and provides less volatile, more robust results than the market-based methodology. The drawback of this approach is that without additional estimates, the specific application can be arbitrary (e.g. weights of indicators, determination of the scope of indicators, setting critical values, etc.) and it is often difficult to separate the risk contribution of the institution from the participation effects.

2.3. Network methods

In addition to the two methodologies described above, network analysis methods are of particular importance as well. These can be used to effectively investigate infection mechanisms in financial networks. Namely, in the event of a financial disruption, interconnectedness increases the likelihood of contagion, the channels of which can be very widespread. The most widespread in the literature is the study of the interbank credit market network. The basic tool of the network approach is the relationship matrix describing the banking system, containing the exposures of each bank to each other. Representing the network as a graph, the introduction of different centrality indicators (proximity, betweenness, degree, weighted degree, eigenvalue centrality, etc.) allows to measure the systemic risk importance of each vertex. *(Müller, 2006)*. However, these approaches do not take into account the risk of contamination, they only measure the importance of the institution in the static network *(Upper, 2011; Allen-Babus, 2009)*. The main drawback of the methodology is that it is very data-intensive, and dealing with incomplete data can be a significant challenge. The measurement of the network effects of interbank markets and the possible channels of contagion have also been addressed by domestic researchers. *Lublóy (2005)* and *Berlinger et al. (2011)* investigated the network effects of the unsecured interbank market, while *Banai et al. (2013)* studied the network effects of the foreign exchange swap market. Also, a promising research direction is the empirical investigation of the so-called multi-layer network approach (internationally, see for example *Aldasoro-Alves, 2017*); *Szini (2021)* in his Hungarian-focused research examined two interbank markets (Hungarian unsecured interbank HUF loan depo and FX swap market) in the same period using network methods, and *Montagna-Kok (2016)* based on Hungarian data analysed the identification of systemically relevant market participants and vulnerable structures of interbank networks using network theory tools.

After reviewing the methods for measuring systemic importance, the next section describes the approach to and the regulation for managing risks arising in the case of systemically important institutions in the European Union.

3. MANAGING SYSTEMICALLY IMPORTANT INSTITUTIONS IN THE EUROPEAN UNION

The leading international forum for international financial regulation, the Financial Stability Board (FSB) headquartered in Basel and the Basel Committee on Banking Supervision (BCBS) of the Bank for International Settlements (BIS), have developed regulatory principles and recommendations to address risks and identify the institutions concerned. The international regulatory standards for systemically important institutions have been implemented by the EU's financial regulation since 2014, and are therefore also applicable in the countries of the Central and Eastern European region and Hungary.

In the context of mitigating risks to systemically important financial institutions, the international recommendation and the local regulations implementing it essentially require the introduction of an additional capital buffer. The capital buffer of a systemically important institution must be set up by the institution concerned as an additional capital requirement per total Risk Weighted Assets (RWA). The size of the buffer depends on the degree to which the institution in question proves to be significant from a systemic risk perspective.

In the CEE region, fundamentally mitigating the risks of Other Systemically Important Institutions (O-SIIs) is of key relevance. The regulation of capital buffers that may be required for these institutions was laid down in the CRD IV/CRR package of regulations[3], the relevant parts of which have been implemented in the laws of the region and the domestic credit institution law.

Under the relevant legislation[4]:

- The capital buffer has to be set up from the best quality own funds (Common Equity Tier 1, hereinafter: CET1);

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[3] DIRECTIVE 2013/36/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 26 June 2013 on access to the activity of credit institutions and the prudential supervision of credit institutions and investment firms, amending Directive 2002/87/EC and repealing Directives 2006/48/EC and 2006/49/EC, and REGULATION (EU) No 575/2013 of the OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 26 June 2013 on prudential requirements for credit institutions and investment firms and amending Regulation (EU) No 648/2012

[4] The relevant domestic legislation is Act CCXXXVII of 2013 on Credit Institutions and Financial Enterprises and Act CXXXIX of 2013 on the Magyar Nemzeti Bank.

- The maximum capital buffer ratio is 2 per cent of the total Risk Weighted Assets (RWA) value, but under CRD V[5] a 3 per cent requirement may already be imposed for O-SII capital buffers, subject to supervisory discretion.
- It has to be reviewed annually (both the list of O-SII institutions and the buffer rate for them);
- The national authority has disclosure and notification obligations in relation to capital buffers.

The legislation allows for different types of capital buffers, depending on the macro-prudential risk(s) that the authorities wish to address. For CRD IV, common rules on capital buffers have also been laid down, which are necessary to have a limit on the accumulation of capital buffers used for the same purpose (this typically occurs in the case of G-SII, O-SII and the systemic risk capital buffers[6]). The values of the G-SII requirement, the O-SII requirement and the systemic risk capital buffer set at the same consolidation level do not add up, but as a general rule the highest of them prevails[7]. The CRD V has amended this framework, and under the current rules the systemic risk capital buffer can no longer be used to deal with O-SII type risks, so the systemic risk capital buffer and the O-SII/G-SII buffer are always additional. If the institution concerned fails to meet these additional capital requirements, restrictions on dividend and performance-related payouts will apply.

To ensure that the treatment of O-SIIs is as consistent as possible across the EU and in line with the requirements for G-SIIs, the EBA has issued guidelines on the methodology for the identification and assessment of O-SIIs[8]. According to the guidelines, the identification will require the aggregation of ten share-based indicators based on four groups of indicators (indicator-based approach). For each of the four groups of indicators, a score between 0 and 10,000 is determined, on the basis of which each institution concerned is also given an

[5] DIRECTIVE (EU) 2019/878 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL amending Directive 2013/36/EU as regards exempted entities, financial holding companies, mixed financial holding companies, remuneration, supervisory measures and powers and capital conservation measures

[6] The complexity of the rules for the application of the O-SII buffer and the relatively low maximum size of the capital buffer have encouraged some EU Member States to apply the systemic risk capital buffer to manage risks associated with systemically important institutions. Although this capital buffer is not specifically targeted at this risk under the regulation, the conditions for its use are very flexible, and the Czech Republic, Croatia, the Netherlands and Sweden, among others, have made use of this asset.

[7] An exception to this is when the capital buffer is required only for domestic exposures, in which case the SRB rate is added to the higher of the G-SII and the O-SII at the given consolidation level.

[8] https://www.eba.europa.eu/-/eba-publishes-criteria-to-assess-other-systemically-important-institutions-o-siis-

aggregate score (the four groups of indicators are given the same weighting of 25 per cent when determining the aggregate score, so scores between 0 and 10,000 are possible for the aggregate score as well). The four groups include indicators representing size, importance (substitutability) of functions in financial intermediation, complexity (derivatives, cross-border exposures) and interconnectedness with financial institutions. Institutions with a score above a fixed threshold (350 points) will be considered O-SIIs in any case, and, in addition, the national authorities may adjust the 350-point standardised threshold within a range of -/+75 points, depending on the specificities of the banking system and the evolution of individual banks' scores. Furthermore, based on a qualitative assessment and additional indicators that better capture national specificities, institutions with a limited deviation from the threshold may be granted an O-SII rating if duly justified by the authority.

With regard to the guidelines, it is important to note that, it only applies to the identification methodology, while the imposition, determination and differentiation of the specific capital buffer is basically a matter for national authorities in the case of non-euro area Member States. Within the euro area, this decision-making power is somewhat shared between the ECB and the national authorities, due to the framework of the Banking Union: the ECB expects national authorities to comply with a stepped lower threshold when setting O-SII capital buffer rates.

An important development in recent times has been the European Banking Authority's desire to address the significant divergence in O-SII capital buffer levels set by the authorities of individual Member States. An important part of the European Banking Authority's mandate under the CRDV[9], which was to be implemented into national law by the end of 2020, was to make proposals to the European Commission for the design of O-SII buffers and for the methodology for their determination.

Having described the approach and regulatory framework for managing the risks posed by systemically important institutions in the European Union, now the main characteristics of systemically important institutions (O-SIIs) identified in the European Union will be reviewed, the decisions of the competent authorities in each EU Member State grouping will be examined

[9] Directive (EU) 2019/878 of the European Parliament and of the Council of 20 May 2019 amending Directive 2013/36/EU as regards exempted entities, financial holding companies, mixed financial holding companies, remuneration, supervisory measures and powers and capital conservation measures.

with regard to the identification of systemically important institutions and capital buffer requirements, and a cluster analysis of EU O-SIIs will also be conducted.

4. EXAMINATION OF THE SYSTEMIC IMPORTANCE SCORE AND THE REQUIRED O-SII CAPITAL BUFFER

Based on 2020 EBA data, a total of 173 O-SIIs have been identified by national authorities in the EU. Since the implementation of the formal notification obligation, the number of O-SIIs identified increased substantially between 2015 and 2017 (from 173 to 203), and then it decreased between 2018 and 2020 to the 2015 level. The change in the number of identified O-SIIs was driven by both new institutions being added and former ones being removed from the list, but often both were driven by acquisitions and mergers. The O-SIIs identified in the EU have a significant market share, with a combined balance sheet total of around €33 thousand billion in 2018, representing 68 per cent of the total EU banking system's balance sheet total *(EBA, 2020).* This is a much more dominant share than the market share of global SIFIs in terms of balance sheet total, which the IMF estimates at around 44 per cent *(IMF, 2017).* At Member State level, this rate is already highly dispersed, with the median at Member State level being 81 per cent, the lowest value 37 per cent and the highest 95 per cent. The ratio of EU O-SIIs' balance sheet total to GDP is also heterogeneous, but in most Member States they play a very important role. The EU average at national level is 182 per cent, but there are examples of rates between 37 and 800 per cent *(EBA, 2020).* A particularly important issue for EU O-SIIs is their capital position. In general, the capital adequacy of EU O-SIIs is high, with an average CET1 ratio of 18.06 per cent at the national level based on 2018 data, although there is also a high degree of heterogeneity in this area, with examples of 6.63 per cent and extremely high levels of 77.3 per cent *(EBA, 2020).*

For our analysis, we used the national notifications and the related database made available by the European Banking Authority (EBA) on its website[10]. The database contains all O-SIIs identified by the competent authorities in the Member States, both for institutions identified through the formal process and for institutions identified through supervisory discretion (173 institutions). The numeric variables used in the analysis are the aggregate systemic importance score for a given institution as determined by the competent national authority and the final

[10] https://www.eba.europa.eu/risk-analysis-and-data/other-systemically-important-institutions-o-siis-

additional capital buffer required by the relevant competent authority for a given systemically important institution. For a total of 125 institutions, in addition to the aggregate systemic importance score, a breakdown by indicator group (Size, Significance (Substitutability), Complexity and Interconnectedness) was also available based on the reports of the competent authorities, and this data was also used in the cluster analysis discussed in the next chapter.

In the period under review, in the EU regulatory framework, the level of the additional capital buffers required for O-SIIs was essentially set at national level by the competent national authorities of the Member States. A relevant question in this context, both for the single market and for the single regulatory treatment, is whether significant differences can be identified between the capital buffer rates set by the competent authorities of different groups of Member States, taking into account also the systemic risk importance of each institution. In our analysis, we have grouped the EU Member States into "new" and "old" as well as "northern" and "southern". The grouping of the EU Member States was essentially based on two approaches that are also used in international analyses. The division between "new" and "old" Member States basically refers to the countries that are supposedly less economically developed, having joined the EU since 2004, and those that have been members for a longer period of time and have a supposedly more developed economic and financial system. The division between "northern" and "southern" groups of Member States uses an approach that has been examined in the EU in several areas (e.g. fiscal discipline in Member States, possibly identifiable differences in labour productivity), i.e. the division between the "southern" Member States considered less strict in the public eye and the "northern" which is often seen as more disciplined in policy terms[11]. Of course, these groupings can be considered somewhat arbitrary, but in general they capture the main differences between the groups of Member States.

In order to examine the difference between "new" and "old" as well as "southern" and "northern" Member States in terms of scores of systemic importance and required capital buffers, a non-parametric Mann-Whitney test was used. Using this test does not require the distributions to be normal, but the distribution curves of the two groups should be similar. Our results show that for the EU's "new" and "old" groups of Member States, no substantive differences can be identified in terms of either the O-SII scores for systemic importance or the O-SII capital buffers required by national authorities, i.e. neither group of Member States can

[11] Croatia, Malta, Cyprus, France, Spain, Italy, Portugal, Slovenia, Bulgaria and Greece were considered as "southern" Member States.

be considered "more stringent" in this respect. In contrast, for the "northern" and "southern" groups of EU Member States, although no significant difference in O-SII scores of systemic importance can be identified between the two groups of Member States, a significant difference in the required O-SII capital buffers can be identified, with the competent authorities in the "northern" Member States typically setting a higher additional capital buffer than those in the "southern" ones.

The result is also important from a policy perspective, as it shows that there is a significant divergence between the competent authority practices of certain groups of Member States in setting the capital buffer rates. On this basis, there may be a regulatory justification for developing more detailed requirements than in the period under review to ensure a more consistent approach at EU level for the appropriate setting of O-SII capital buffer rates, so that similar unjustified divergences can be addressed at EU level. The main findings of the EBA's "Report on the Appropriate Methodology to Calibrate O-SII Buffer Rates", published in December 2020, also point in this direction (for more details see *EBA, 2020*).

5. CLUSTER ANALYSIS OF SYSTEMICALLY IMPORTANT INSTITUTIONS IDENTIFIED IN THE EUROPEAN UNION

In the foregoing, an empirical analysis of the competent authority decisions of EU Member State groups was conducted in relation to the defined systemic risk importance score and the capital buffer requirements for O-SIIs. In this chapter a cluster analysis of the systemically important institutions identified in the EU is summarized, for a somewhat smaller set of institutions than in the previous analysis. As indicated above, for the full O-SII scope identified in 2020, only the aggregate score for aggregate systemic importance and the required O-SII capital buffer were available, but for a slightly smaller group of institutions, in addition to the aggregate systemic importance score, a breakdown by indicator group (Size, Importance (Substitutability), Complexity and Interconnectedness) was also available based on the notifications of the competent authorities. Thus, for a total of 125 O-SIIs – which is 72.3 per cent of the total EU-wide O-SII population – a deeper cluster analysis can be carried out by including indicator groups.

In the cluster analysis, first dimensionality reduction was performed by Principal Component Analysis (PCA) using the four indicator groups set out in the EBA Recommendation[12]. Although the range of data available is far from ideal for the application of Principal Component Analysis, the results are relatively easy to interpret. Based on these, two main components have been identified. One component captures the importance of the institution's interconnectedness with other institutions, i.e. how important its role is due to its interconnectedness and complexity with other institutions ("Interconnectedness Factor"), while the other component captures the importance, i.e. how important the institution is, how difficult it is to substitute it in the given banking system due to its size and banking activities ("Substitutability Factor"). Based on these two factors identified in the Principal Component Analysis and the O-SII capital buffers required by the respective competent national authority, a cluster analysis of the O-SII institutions available in the database was performed using both hierarchical cluster analysis and *k*-means cluster analysis. The results of the *k*-means cluster analysis are presented in more detail below.

Table 1: Cluster centres in relation to the *k*-means cluster analysis

	Clusters				
	1	2	3	4	5
Final O-SII capital buffer	1.31%	1.32%	1.70%	2.25%	0.61%
Interconnectedness factor	1.35768	-.88407	.25621	3.87911	-.35119
Substitutability factor	-.55450	1.62795	.95915	.87953	-.56765

Based on the dendrogram using the Ward method and the "elbow" method, 4–5 clusters should be identified in the hierarchical cluster analysis (for the methodology, see for example *Kovács, 2014; Szüle, 2016*). Based on these results, 5 clusters were recorded in the *k*-means cluster analysis. An important feature of the *k*-means cluster analysis procedure is that it is possible to analyse and interpret the centres of each cluster. These can also be used to identify the main characteristics of each group (cluster), i.e. to determine which systemically important institutions with which characteristics are found in each cluster. Since standardised variables

[12] In addition to the principal component analysis, we have also investigated the possibility of applying Principal Axis Factoring (PAF) to the data concerned. Based on our examination of using PAF, the use of PCA was found to provide more interpretable results for cluster analysis, so in our analysis the latter was included.

were used in the cluster analysis, in the interpretation positive values mean above-average level, while negative values mean below-average level (Table 1).

Based on the cluster centres, the following main clusters can be distinguished for the systemically important institutions identified in the European Union:

1. "Network" O-SIIs: For these institutions, the interconnectedness factor is well above average, but they are not particularly large either in size or in terms of the core financial services they provide to the real economy. For the O-SIIs included here, a slightly higher than average capital buffer of around 1.3 per cent is required.

2. "Large but less complex" O-SIIs: The institutions in the second cluster have the highest substitutability factor compared to all other clusters, well above average, but the lowest values in terms of interconnectedness. The size of these institutions is significant and they are also very difficult to substitute in terms of deposits and loans to the real economy. Also for these O-SIIs, a slightly higher than average capital buffer of around 1.3 per cent has been imposed by the competent national authorities.

3. "Traditional" O-SIIs: For these institutions, both the interconnectedness factor and the substitutability factor are above average. The size of these institutions is significant, and they are also difficult to substitute in terms of deposits and loans to the real economy. For the O-SIIs included here, a higher than average capital buffer of around 1.7 per cent is required.

4. "Too big and complex to fail" O-SIIs: The O-SIIs belonging here are the most systemically important institutions. They have a high value in terms of both interconnectedness and difficult substitutability, and their role and complexity in the inter-institutional network is outstanding. For these O-SIIs, the highest possible capital buffer has been set, averaging 2.25 per cent, which is possible because several countries require them to hold the maximum of the systemic risk buffer requirements, i.e. a capital buffer of 3 per cent.

5. "Less big and complex" O-SIIs: The fifth cluster includes the "least" significant O-SIIs. For these institutions, both the interconnectedness factor and the substitutability factor are below average. Neither their size nor their complexity is

outstanding in the banking systems concerned, and in many cases they have been identified at supervisory discretion. For the O-SIIs included in this category, a capital buffer of 0.61 per cent on average is required, which is considerably lower than the average.

A possible cluster analysis of EU O-SIIs has been presented above, where five possible clusters have been identified. In the next chapter, the impact of notifications made by competent national or EU authorities on the market value of other systemically important institutions will be analysed.

6. THE IMPACT OF NOTIFICATIONS BY COMPETENT AUTHORITIES ON THE MARKET VALUE OF OTHER SYSTEMICALLY IMPORTANT INSTITUTIONS IN THE EUROPEAN UNION

In line with EU legislation, each designated national authority, typically macro-prudential, must publicly disclose annually from the end of 2015 which institutions are considered systemically important in its Member State. Regarding the banks thus classified as Other Systemically Important Institutions (O-SIIs) in EU terminology, the authorities must also communicate the score according to the EBA Core Methodology, which measures their systemic importance. Public identification had to be carried out for the first time by the end of 2015, and the authorities of countries could perform the publication by the end of 2015. The full EU-wide O-SII list was published by the European Banking Authority (EBA) on its website on 25 April 2016 in a uniform format.

The consolidated EU regulation and mandatory disclosure may also provide an opportunity to examine the impact of public official notifications on the market value of the systemically important banks concerned, both at the EU level and focusing on the CEE region. Several studies have already been conducted on this issue for globally systemically important institutions (see, among others, *Moenninghoff et al., 2015; Bongini et al., 2015*), and such an analysis has been conducted at EU level (see *Andrieș et al., 2020*), but, to our knowledge, no similar in-depth analysis is currently available for other systemically important institutions identified in the Central and Eastern European region. In addition to the notification of the identification of systemically important institutions, the ECB official notification in response to the coronavirus outbreak provides a unique opportunity to analyse the impact of the competent authority's notification on the market value of systemically important institutions.

In order to address the economic challenges posed by the coronavirus pandemic, the ECB, acting as the supervisory authority for commercial banks in the euro area, announced on 12 March 2020 that banks supervised under the Single Supervisory Mechanism (SSM) (which effectively includes all O-SIIs active in the euro area) will temporarily not be subject to Pillar 2 capital requirements and capital conservation buffers. Although the notification did not directly affect the capital buffers of systemically important institutions, the temporary exemptions granted for two very significant capital items are also relevant for systemically important institutions, so it is worth examining the impact of this official notification on the market value of systemically important institutions in the euro area. As far as we are aware, no such analysis has yet been carried out in relation to this event.

Three main questions are examined below. Firstly, similar to the analysis of *Andrieș et al. (2020)*, we review whether the EBA's official notification on 25 April 2016 had a significant impact on the market value of EU O-SIIs (i). Secondly, we examine the impact on the market value of systemically important banks in Central and Eastern Europe of the official notifications of O-SII listings by national authorities in 2015–2016 (ii). Finally, we also present whether the ECB's 12 March 2020 official notification of a temporary capital buffer release in response to the coronavirus pandemic can be identified as having a significant impact on the market value of systemically important euro-area institutions.

Our analysis focused on systemically important financial institutions in EU Member States. Only institutions whose shares are listed on the stock exchange have been included in the sample, so that the theoretical impact on shareholder value can be captured. 57 O-SIIs have been identified where a stock exchange share price was also available in the context of our assessment of the impact on the market value of the EBA's official notification on 25 April 2016. For the systemically important banks in Central and Eastern Europe, a total of 24 institutions were provisionally identified from the analysis of official notifications related to the O-SII list by Member State authorities during 2015, using data from Austria, Hungary, Slovakia, the Czech Republic, Poland, Romania and Bulgaria. Unfortunately, the Slovenian O-SIIs had to be excluded from the sample due to significant resolution events in several of the institutions concerned during this period and the rather low market liquidity of the local banks' shares. These two effects would have significantly distorted the results, so they are not included in the sample of Eastern European banks. Also excluded from the sample were banks in the region whose shares were not sufficiently liquid, i.e. not traded for at least 80 per cent of the possible trading days (HPB in Croatia, GetinNobel and ING in Poland, and the Slovakian VUB and Tatra[13]). In total, 19 institutions were included in the sample of Eastern European banks. Finally, to examine the impact of the ECB's official notification of a temporary capital buffer release due to the coronavirus pandemic, all O-SIIs identified and listed in euro-area Member States were included in the sample. In total, 37 institutions were surveyed for this question. It is worth noting that, although these samples may seem methodologically quite small, no sample of a different size has been used for G-SIFIs in the international literature *(Moenninghoff et al., 2015; Bongini et al., 2015;* for an EU-wide study see *Andrieș et al., 2020)*. This is mainly because the scope of the question itself focuses on a relatively small sample of systemically important financial institutions (20–60 institutions), so it is worthwhile to conduct empirical studies taking these limitations into account.

For the analysis, we used the share prices of the banks in the sample available in the databases of Bloomberg, Datastream and Fitch SNL, the stock market indices used in the country in question, in line with standard practice in event studies, the STOXX Europe 600 and Euro Stoxx 50 European stock indices and the MSCI World global stock index. For the latter, we also used data from the Bloomberg and Fitch SNL databases. The date of 25 April 2016 was used to define events for the EU-wide analysis, the specific date of public official notifications for the study with Central and Eastern European focus, and the date of 12 March 2020 for the analysis of the impact of the ECB's official notification on the temporary capital buffer release due to the coronavirus pandemic

In our research, we used the "event studies" approach, which is quite widespread in the literature and is also used by *Keown-Pinkerton (1981), Moenninghoff et al. (2015)* and *Andrieș et al. (2020)*. In order to estimate the impact of official notifications on the share values of O-SII banks, we have produced daily average abnormal returns. The value of the daily average abnormal return indicates the impact of the notification event on the market values of the banks under review. To measure abnormal returns, we have used the market model approach, which has several occurrences in the literature, where the difference arises from the divergence of the return on the given bank's shares and the return of a broader stock index (or a European/global stock index) in the bank's country:

$$R_{it} = \alpha_i + \beta_i R_{mt} + \varepsilon_{it}, \text{ where } E[\varepsilon_{it}]=0 \text{ and } Var[\varepsilon_{it}]=\sigma^2$$

[13] Due to low liquidity in the shareholders' market, also Slovakia was unfortunately excluded from the sample along with Slovenia.

The following procedure was used for the estimation. For each O-SII bank share (i), we calculated the abnormal return (ε_{it}) for the given event window, relative to the bank's "expected" return ("expected" R_{it}) estimated by the market model for the tth period. To do this, the parameters of the market model (α_i, β_i, σ^2) were estimated using the data available in the estimation window. In this framework, a negative value of the abnormal return (ε_{it}) means that the market value of the bank decreases as a result of the notification, while a positive value means that it increases[14].

A critical point in event analysis is the definition of appropriate estimation and event windows. In our study, we used the same approach as in the relevant literature *(Moenninghoff et al., 2015; Campbell et al., 2010; Andrieș et al., 2020)*: We considered a 150-day estimation window in the base case and +/- 1 day relative to the event in the event window. In the analysis, the results were checked by both robustness test and statistical tests. During the robustness test, several samples were tested, leaving out and filtering out possible outliers. In the event testing dimension, we tested the robustness of the results by varying both the length of the estimation window (100 vs. 150 days) and the duration of the event window. The significance of the results was tested using a parametric *t*-test.

6.1. Impact of the EBA's official notification concerning O-SII identification on 25 April 2016

Three approaches were used to examine the EBA 2016 notification. Firstly, we examined the cumulative abnormal returns (CAR) and cumulative average abnormal returns (CAAR) for the entire event window using country (Member State) level stock indices. Secondly, the analysis was also carried out using European stock indices (the broader STOXX Europe 600 and the Euro Stoxx 50 which focuses on European blue chips). Thirdly, for a broader context, we have also produced abnormal returns relative to a global stock index (MSCI World).

[14] It is worth noting that the share price movements of a systemically important large bank can have a significant weight in small local market indices, with some institutions' share weights of up to 30 per cent in the case of O-SIIs in Central and Eastern Europe, which could significantly distort our results. To address the problem, knowing the price and yield of the given bank share and its weight in the stock index of the given country (based on the Bloomberg and Fitch SNL databases), we produced a "virtual" stock exchange index for the event window, excluding the given O-SII share, and used these in our analysis of O-SIIs in Central and Eastern Europe.

Using country-level stock indices, we could not identify significant abnormal returns in either the positive or negative direction in the case of the 2016 EBA notification. Using European stock indices, a significant negative cumulative average abnormal return was identified for the broader STOXX Europe 600, but only at a significance level of 10 per cent and for only one event window. Using the Euro Stoxx 50, no significant effect could be identified, while a negative cumulative average abnormal return could be identified relative to the MSCI World global stock index, but again only at a 10 per cent significance level and for only one event window.

6.2. The impact of Member State official notifications on O-SIIs in the Central and Eastern European region

In addition to analysing the impact of the 2016 EBA notification on all EU O-SIIs, we also looked at the identifiable impacts with a focus on the Central and Eastern European region. In the case of O-SIIs in Central and Eastern Europe, we see a weak positive effect on the market value of O-SIIs, at a 10 per cent significance, when looking at the national official notifications concerning the identification.

By removing the possible outlier (the Polish BHW Bank), the significance of the effect increases substantially. The exclusion may be justified by the fact that this bank is part of Citigroup and that during the period under review there were a number of question marks about the group's regional activities (in this period the group announced the sale of its Hungarian and Czech retail portfolios and there was a possibility that other markets could be affected by the exit).

The results obtained for the Central-Eastern European O-SIIs are broadly in line with those of *Moenninghoff et al. (2015)* and *Andrieș et al. (2020)*, and in addition the direction and magnitude of the effect for the outlier-free estimation are similar to those obtained in the latter study (1.07% vs. 1.2% for the T, +/-1 day estimation window). The significant positive effect may point in the direction that, for some institutions, the effect of the emergence, the "pronouncement", of a specific explicit state guarantee may already be stronger than the costs of capital and administrative burdens associated with systemic importance, which is somewhat contrary to the original regulatory intention.

6.3. The impact of the ECB's official notification of the release of the temporary capital buffer in the wake of the coronavirus pandemic

In addition to examining the impact of official notifications on O-SII identifications, our research also studied the impact of the ECB's official notification of a temporary capital buffer release in response to the coronavirus pandemic. For this question, we used market indices similar to those used for the EBA's 2016 notification and estimated cumulative abnormal returns and cumulative average abnormal returns: country (Member State) level stock indices, European stock indices (STOXX Europe 600 and Euro Stoxx 50) and global stock indices (MSCI World).

In the context of the results, it can be seen that, although no substantive significant effect can generally be identified when using country-level stock indices, a considerable and significant negative effect can be identified for the use of European and global equity indices in the context of the ECB's 12 March 2020 official notification on the temporary capital buffer release.

To summarise the results for our sample of official notifications, we find that for systemically important banks in Central and Eastern Europe public national official notifications regarding the O-SII list may have had a rather positive impact on the market value of the institutions concerned, but the effect is not very robust, partly due to the individual effects and the relatively small sample size. In contrast, in the case of the 2016 EBA notification, there was little evidence of a significant impact, with only the STOXX Europe 600 and MSCI World applications showing a negative cumulative average abnormal return, but only at a significance level of 10 per cent, so it is less possible to draw a firm conclusion from this outcome. Finally, a material and significant negative impact can be identified in the case of the ECB's 12 March 2020 official notification of the temporary capital buffer release in response to the coronavirus pandemic. One likely interpretation of this result could be that, because of the temporary nature of the notification, the investors did not view it positively, as the capital buffers indicated will have to be re-established once the risks of the pandemic have disappeared, i.e. it is not a permanent allowance. In addition, in this situation, investors may have preferred higher capital adequacy, so the temporary reduction in capital buffers may have also carried the risk that the management may consider lower capital adequacy to be temporarily sufficient due to the relaxation of regulations.

From a policy perspective, the above results suggest two possible directions. On the one hand, the O-SII rating of an institution – presumably mainly due to the implicit state guarantee becoming "explicit" – tends to have a positive effect for investors, as they may perceive the riskiness of the institution as substantially lower. On this basis, it makes sense for regulators to have effective and workable resolution frameworks and tools in place to minimise the likelihood of an O-SII having to actually use the state guarantee that has been "explicitly" made available by the O-SII identification. On the other hand, however, the results also show that in a crisis situation, the investors' valuations may not necessarily be positive about a temporary relaxation of capital requirements, as capital buffers have to be re-established once the problem situation is resolved. In these situations, the investors may prefer a higher capital adequacy, so policy makers may prefer to support the systemically important institutions concerned by other means (e.g. state guarantees for certain exposures, special loan schemes, preferential or even designated funding, etc.).

In this chapter, the impact of official notifications made by competent national and EU authorities on the market value of other systemically important institutions at EU and regional level was analysed. In the following section, an alternative approach is presented to the allocation of systemic risk and the determination of the additional capital buffers of O-SIIs in the domestic banking system.

7. SYSTEMIC RISK ALLOCATION AND ALTERNATIVE ALLOCATION OF ADDITIONAL CAPITAL BUFFERS OF SYSTEMICALLY IMPORTANT INSTITUTIONS IDENTIFIED IN HUNGARY BASED ON SHAPLEY VALUE[15]

The issue of risk allocation has been quite extensively researched in the literature, presumably also because of the many possible application areas (see inter alia *Denault, 2001*; *Valdez-Chernih, 2003; Kalkbrener, 2005*; *Buch-Dorfleitner, 2008;* or *Boonen et al., 2012*). *Csóka et al. (2009)* investigated the applicability of game theory methods to risk allocation, noting in this regard that a stable risk allocation method can always be found, and that even if the risk environment changes, the risk can be allocated in such a way that none of the coalitions of actors opposes it (see also *Csóka-Pintér, 2016*). According to *Tarashev et al. (2009)* and *Drehmann-Tarashev (2011)*, previous ES measures, defined under the assumption of systemic losses, are limited in their ability to capture the systemic importance of an institution, and therefore they propose the use of the Shapley value concept of the cooperative game theory to measure risk allocation on a contribution basis. The risk measure for a surveyed institution is obtained by determining the average systemic ES increment after adding the surveyed

[15] This chapter is mainly based on the *Fáykiss-Hevér (2022)* study.

institution to various combinations of sub-networks. One of the benefits of the measurement based on the Shapley value is efficiency, i.e. the sum of the risks of each institution equals the risk measured at the system level. Another advantage of the approach is the feature of the Shapley value that it treats all as equals, i.e. that the capital requirement allocated to two equivalent sub-units is the same.

In this research, we mainly use the approach of *Tarashev-Zho (2008)* and *Tarashev et al. (2015)* based on the Shapley value in relation to the allocation of systemic risk among systemically important institutions identified in the Hungarian banking system.

Tarashev et al. (2015) determine the systemic risk to be distributed from the aggregate loss distribution using VaR and ES, and then, within that, apply two different characteristic functions ("fixed distribution tail" and "variable distribution tail"). It uses the Shapley value based on cooperative game theory to allocate risk. In the following, we will use this approach – different from the current EBA score approach – in order to define alternative additional capital buffer levels for domestic systemically important institutions. Indeed, the capital buffers determined in this way provide an opportunity to compare the results of the alternative capital buffer allocation method based on the Shapley value with the results of the method in the current regulation, which is essentially based on the EBA scoring procedure. It is worth pointing out that, in line with the approach of *Tarashev et al. (2015)*, in the empirical sections we typically use the Shapley value not in the sense of nominal risk allocation, but rather denote the share of systemic risk as the Shapley value.

The Shapley value, within a game theory framework, tries to capture how the outcome of cooperation can be fairly distributed according to certain principles, i.e. how, in our case, systemic risk can be allocated among individual institutional actors. Taking all permutations of possible cooperative sub-units into account, the method allocates to a given actor its average marginal contribution to coalitions consisting of sub-units (see inter alia *Shapley, 1953; Tarashev et al., 2015*).

In the methodology we used, the starting data is the distribution of individual losses of domestic banks and the aggregate losses of the banking system, where the distribution of losses realized in the event of failure for each bank under study is estimated. This was done by estimating an LGD (loss given default) * EAD (exposure at default) for each bank based on its debt composition (taking into account the level of insured deposits in the banking system), multiplied by a characteristic function, which is 1 if the value of the given bank's assets falls below the default threshold and 0 otherwise.

The value of each bank's assets is simulated using estimated common and idiosyncratic factors, and the loss distribution of the entire banking system and each subsystem is obtained by aggregating the loss distribution of each institution. As risk measures, in line with the article of *Tarashev et al. (2015)*, we used VaR and ES based on aggregated loss distributions for different subsystems.

Based on *Tarashev et al. (2015)*, the V_i value of the assets of the bank $i \in \{1,2,3,\dots,n\}$ assets varies over a period as a function of a common and a unique factor:

$$\frac{V_i - V_0}{V_0} = \sigma_i(r_i\, M + \sqrt{1 - r_i^2}\; Z_i),$$

where V_0 is the initial asset value; σ_i is the standard deviation of the change in asset value; *M* is the common factor; Z_i is the idiosyncratic factor; $r_i\ a$ is the common factor loading; and $\forall i \in \{1,2,3,\dots,n\}$ Z_i, *M*, and $Z_{i\neq j}$ are independent probability variables with standard normal distributions.

The value of the characteristic function $\overline{L_\iota}$ is 1 if the value of bank *i*'s assets falls below the bankruptcy threshold ($V_0 + \sigma_i \phi^{-1}\,(PD_i)$) (i.e., it goes bankrupt), and 0 otherwise, i.e.:

$$\overline{L_\iota} = \begin{cases} 1, if\ r_i\, M + \sqrt{1 - r_i^2}\; Z_i\ < \phi^{-1}\,(PD_i) \\ \qquad 0, otherwise. \end{cases}$$

For the bank $i \in \{1,2,3,\dots,n\}$, the loss is $L_i = \phi_i \overline{L_\iota}$, where in the case of bankruptcy ϕ_i is the loss of that bank.

In our analysis, we used data from the eight other systemically important institutions (O-SIIs) identified in Hungary. The value of the bank's assets is estimated by *Tarashev et al. (2015)* were simulated using the r_i factor loading values determined from the correlation matrix between the bank asset value changes and the normally distributed common and individual factors, but since Moody's KMV data are available for only a few domestic systemically important institutions, bank asset values, bank losses, and the common factor loadings (r_i)) were estimated using the MNB bank balance sheet databases, while the PDs of individual systemically important institutions were determined using the PD_i probability of failure values based on the FitchRatings transition matrix from 1990 to 2020, taking into account the risk ratings of the institution. Using this data, Monte Carlo simulation was used to generate the distribution of the banks' L_i losses. The loss distributions for the banking system as a whole and for the sub-systems under study were obtained by aggregating the individual loss distributions of the banks, and the VaR and ES from the loss distributions aggregated for the different sub-systems, as presented earlier, were used as risk measures.

In determining alternative additional capital buffers for domestic systemically important institutions based on the Shapley value, the December 2021 balance sheet data were used as the initial asset value (V_0) of institutions for model calibration. The institution-level standard deviations (σ_i) calculated from annual changes in asset values are derived from annual asset changes between 2004 and 2021, and similarly the correlation matrix calculated from annual asset value changes for institutions is estimated.

To simulate the distribution of losses realised in the event of bankruptcy, we estimated a ϕ_i value (the size of the loss realised in the event of bankruptcy) based on the liability side of each bank, considering the level of deposits insured, and multiplied it by the characteristic function. As a novel element of our research, unlike similar estimates (e.g. *Tarashev et al., 2015)* – when estimating realized loss ϕ_i, we not only considered the external debt stock of the institution in question separately, but also the mitigating effect of the stock of insured deposits as one of the most important liability-side elements. This provides a more accurate estimate of realised losses, as realised losses are mitigated by insured deposits from households and companies, which are paid out to the stakeholders by the deposit guarantee scheme. Although the impact of these payments may be felt in the banking system over time – for example, banks may have to pay higher deposit insurance contributions due to the need to replenish the deposit guarantee fund – in the short term, this does not translate into realised losses for real economic agents.[16]

[16] The implicit assumption here is that the National Deposit Insurance Fund (NDIF) will always have enough liquid assets for deposit insurance, or if not, it can borrow with a government guarantee for a short period from the central bank and then replace it with funds from the banks (extraordinary payments, bond issues, etc.) which is paid later by the bankers in the form of higher deposit insurance premiums. In this case, although the State guarantees the NDIF's bonds, it does not need to finance them directly. Recent domestic experience confirms this implicit assumption, as in cases where the assets managed by the NDIF were not sufficient to make deposit insurance payments in the event of the bankruptcy of an institution, the NDIF issued bonds or took loans from banks with a state guarantee, and was thus able to make deposit insurance payments (see for example the implementation of NDIF payments in the context of the bankruptcy of the domestic Sberbank in March 2022).

For each institution, in the absence of individual institutional data, the same insured deposit ratios were assumed for household and corporate deposits separately, but heterogeneity between institutions could still be observed due to the different resource mixes (90 per cent insured deposit rate for household deposits and 30 per cent for corporate deposits were assumed by default). In the robustness test, we also examined the extent to which the simulation results change under different household insured deposit ratios.

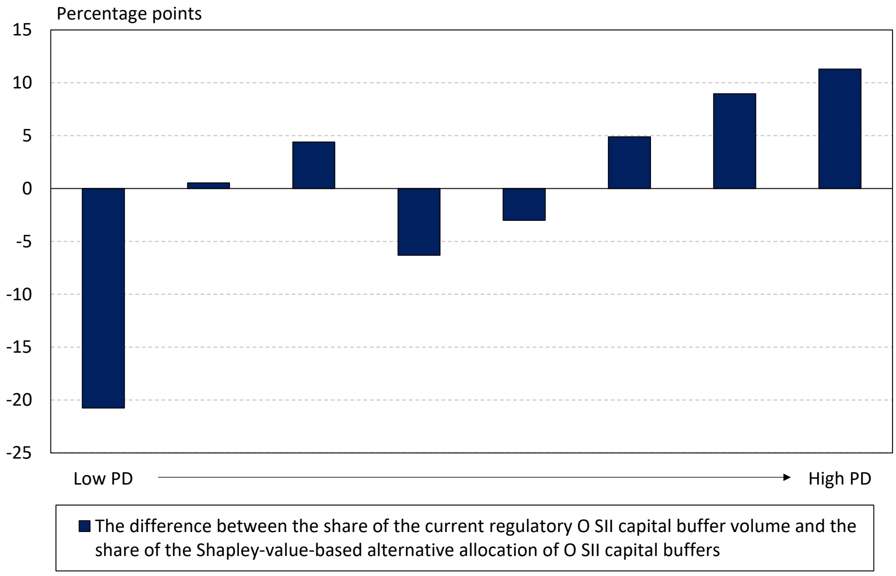
As a first step in the simulation, Principal Component Analysis was used to determine the r_i factor loading values based on the correlation matrix determined from the banks' annual asset value changes. To estimate the loss distribution functions of the banks, 2 million states of the world were simulated, whereby the common and individual components with normal distribution, with expected value 0 and standard deviation 1 in the given world state were determined, as well as the changes in asset value for each institution using the factor loading values and the generated components. It was then identified whether the institution went bankrupt, and the individual loss was also determined for each institution in the given state of the world. Based on the runs, we determined the aggregate loss distribution functions for each institution and for all possible coalitions of institutions, and then calculated VaR and ES based on *Tarashev et al. (2015)* using the individual loss distribution functions, the distribution functions for each coalition and the aggregate loss distribution function for the banks under study. Finally, the VaR and ES values determined for the banking system as a whole were distributed to each systemically important institution using a Shapley value. The results of applying the ES risk measure and the variable distribution tail approach are described in more detail; based on our simulations, this approach was found to be the most applicable.

Our results show that as the ES level decreases, the concentration of systemic risk allocation based on Shapley value also decreases, i.e. it decreases for banks with high Shapley value, while it relatively increases for institutions with lower Shapley value. In a robustness test of the results of the Shapley-value-based systemic risk allocation, the extent was examined to which the Shapley values of the institutions concerned change when different insured deposit ratios are assumed and when a correlation matrix based on ROA (return on assets) is used in the simulation instead of a correlation matrix calculated from the annual change in asset value. Based on the tests, our results proved to be robust.

Using the results presented here, it is worth examining how the allocation of the incremental systemic risk capital buffer of the O-SIIs identified in Hungary would change if it were based on the Shapley value of each institution rather than the methodology prescribed by the current regulation. In the context of the alternative Shapley-value-based allocation of the additional capital buffers of the systemically important institutions identified in Hungary, it was first necessary to estimate an alternative aggregate O-SII capital buffer at the banking system level. This was approached by the difference between the estimated total systemic risk loss calculated from the correlation matrix of annual asset value changes (this systemic risk loss takes into account the correlations between the asset returns of individual institutions, and hence the resulting additive risks, in the model) and a hypothetical systemic risk loss assuming a correlation between zero asset value changes (this systemic risk loss theoretically does not take into account the dimension of systemic risk that is the "excess" risk arising from correlations between institutions). The banking system level alternative aggregate O-SII capital buffer resulting from this method was about 35 per cent higher than the amount resulting from aggregating the current regulatory O-SII capital buffers. To determine the alternative O-SII capital buffers at the institutional level, the alternative aggregate O-SII capital buffer quantity estimated in this way was allocated to each bank on the basis of the Shapley value, i.e. the share of the institution in the alternative aggregate O-SII capital buffer quantity was determined at the institutional level.

As shown in Chart 1, our results suggest that the Shapley-value-based alternative O-SII capital buffer allocation method would substantially change the institution-level O-SII capital buffer shares for domestic systemically important institutions. The impact essentially appears in two dimensions. On the one hand, we find that the change is substantial at the tails of the PD distribution, i.e. for O-SIIs with relatively low and relatively high PD. Institutions with a low PD would have a considerably lower O-SII capital buffer share compared to the current regulatory O-SII capital buffer requirement, while institutions with a higher PD would have a substantially higher O-SII capital buffer share. On the other hand, the difference between the share of the current regulatory O-SII capital buffer and the share of the Shapley-value-based alternative allocation O-SII capital buffers shows that the change would be smaller for institutions with a relatively "average" PD among O-SIIs, and that the difference in PD levels is probably less determinant for these banks, with the change in share being driven by the evolution of factor loadings.

Chart 1: The difference between the share of the current regulatory O-SII capital buffer volume and the share arising from the Shapley-value-based alternative allocation of O-SII capital buffers for domestic systemically important institutions



Note: Using an Expected Shortfall risk measure and a variable distribution tail at ES (99.9) level. Individual bank PD data are not shown due to possible identification.

8. SUMMARY

In conclusion, it can be established that the problems of overly large and complex financial institutions can involve significant sacrifices for real economy as well as burdens for the public budget. In addressing risks, it is necessary to accurately define the scope of systemically important institutions and to identify the most effective ways to mitigate the associated risks. Although the current regulatory framework essentially mitigates risks through the imposition of an additional capital buffer, the use, mechanisms and effectiveness of alternative regulatory instruments should be explored in the future, taking into account the specificities of each banking system.

In the light of the results, it is worth highlighting the problem that international regulation essentially seeks to address the risks of systemically important institutions by raising capital requirements. Apart from the fact that above a certain size and complexity, the level of capital buffers that can be imposed may not be a sufficient deterrent to the build-up of risk, the strong capital position of large banks in the EU, and within it in Central and Eastern Europe, means that capital buffers can only be moderately effective. Another important future research issue could be the situation and risk mitigation options of systemically important branches including the increasingly dynamic FinTechs, neobanks which may play an increasingly important role in the future in the EU banking systems in the context of cross-border services. The question is to what extent the limits set by the EU regulation can mitigate the build-up of risks and address the problems. The risks arising from the operation of systemically important institutions may therefore be addressed by other, alternative regulatory instruments, the examination of the mode of action of which and the review and empirical measurement of the impact of possibly introduced instruments on O-SIIs could also be a promising research direction.

In addition to the definition of O-SII capital buffers for institutions with systemically important risk, the imposition of a more complex set of requirements, such as stricter liquidity or funding rules (see for example *Adrian, 2015*), may also be an important area for future research. This would not mitigate the risks from a solvency point of view, but would strengthen the liquidity, funding or other network functions of the institutions. The probability of different shocks related to systemically important institutions would then be reduced.

Finally, extending the institutional scope somewhat, the systemic importance of large technology service providers (BigTechs) could be a very promising line of research. An important development in technological developments in recent years is that they can also be relevant at systemic level, for example cloud services provided by large technology companies to financial institutions, or mobile payments or even other financial services provided by international technology companies. The question of how these institutions could be identified within the regulatory framework, and subsequently what possible means could be found to mitigate systemic risks, may be relevant not only in the European Union but also globally.

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