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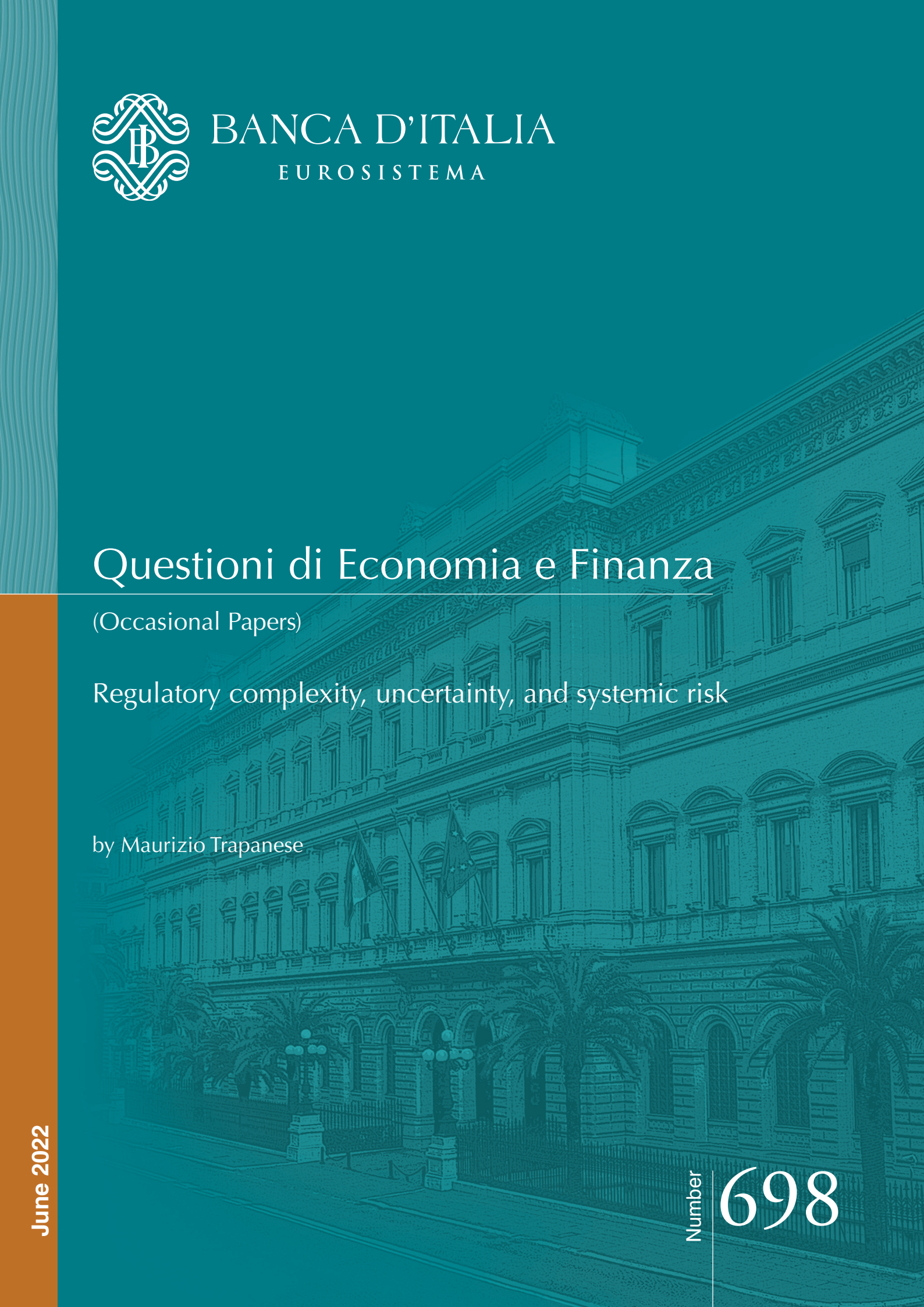

Questioni di Economia e Finanza

(Occasional Papers)

Regulatory complexity, uncertainty, and systemic risk

by Maurizio Trapanese

June 2022

Number 698

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REGULATORY COMPLEXITY, UNCERTAINTY, AND SYSTEMIC RISK

by Maurizio Trapanese*

Building upon the distinction between measurable risk and uncertainty, this paper outlines the fundamentals of the main regulatory frameworks of the last two decades (with a focus on the Basel Accords). The resulting outcome in terms of excessive regulatory complexity might turn out to be costly, and sub-optimal for crisis prevention. Since modern finance is characterised by uncertainty (rather than risk), less complex rules could be given greater consideration. Rebalancing regulation towards simplicity, a step that has been undertaken with the final Basel III Accord, may encourage better decision making by authorities and regulated entities. As addressing systemic risk in a complex financial system should not entail the replacement of overly complex rules with overly simple or less stringent regulations, the real challenge is to define criteria and methods to assess the degree of unnecessary complexity in regulation. To this end, the paper proposes some options affecting the content of the rules, the regulatory policy mix for certain financial sectors, as well as the rulemaking process.

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* Bank of Italy. Directorate General for Economics, Statistics and Research.

"I confess that I fear we are in danger of becoming excessively complicated and that if so we may miss the wood from the trees" Handwritten comment of a Deputy Governor of the Bank of England on a banking reform proposal in 1974. Bank of England Archive 7A222/2.

"The practical difference between the two categories, risk and uncertainty, is that in the former the distribution of the outcome in a group of instances is known, while in the case of uncertainty this is not true." R. Knight (1921), "Risk, Uncertainty and Profit".

"As you do not fight fire with fire, you do not fight complexity with complexity. Because complexity generates uncertainty, not risk, it requires a regulatory response grounded in simplicity, not complexity. (…) In financial regulation less may be more". A. G. Haldane (2012), "The Dog and the Frisbee".

"There is a line among the fragments of the Greek poet Archilochus which says "The fox knows many things, but the hedgehog knows one big thing". (…) For there exists a great chasm between those, on one side, who relate everything to a single central vision, one system, (…) and, on the other side, those who pursue many ends, often unrelated and even contradictory …" I. Berlin (1953), "The Hedgehog and the Fox. An Essay on Tolstoy's View of History".

1. Executive Summary[1]

The modern financial system has become increasingly complex over the years. Economic research has defined this complexity essentially in terms of increased variety of typologies of financial intermediaries, augmented supply of complex (and often opaque) financial instruments, longer intermediation chains, greater interconnectedness among financial sectors, with the potential to facilitate the diffusion of adverse shocks across markets.

Authorities have responded to this complexity through increasingly complex modelling and risk management tools, often borrowed by the intermediaries' practices, underpinned by even more complex rulebooks. The resulting growth in complexity and length of regulatory texts, the potential interactions between different rules, and the increasing difficulties embedded even in their linguistic

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comprehensibility, have raised concerns that the commitment to prevent future financial crises may have led to excessive regulatory complexity, bringing about a number of unintended consequences.

The theoretical foundations of the regulatory frameworks built in the last decades can be found mainly in models of decision-making under risk, which assume that the probability distribution of all possible states of the world is known (and calculated) by economic agents. The underlying assumption of all these models is that information can be acquired and processed at a cost that is close to zero, implying that the availability and use of more information always bring to better decisions and greater effectiveness. Based on these theoretical premises, the models and tools developed for decision-makers have required high degrees of precision and complexity.

Policy decisions based only upon over-detailed models may however produce catastrophic errors. This is the mechanism that lies behind the Goodhart's Law, according to which any statistical regularity (regarding a particular metric) tends to collapse once that metric becomes a policy target or is used for control/regulatory purposes. When crises occur, such a policy framework can make responses less effective, aggravating the costs of the crises.

Contrary to this approach, over the years several economists (for example, Knight, Keynes, Hayek, Simon) have suggested that uncertainty, rather than measurable risk, is the normal context of decision-making. Assigning probabilities in an economic or financial system can be particularly difficult non only when dealing with rare, high impact events, but also because the system can be very sensitive to small changes in initial conditions, leading to very different outcomes. As a result, there may be few, if any, parameters in economic or financial models able to meet the Lucas critique, i.e., being considered invariant with respect to changes in policy choices. Over the years, the so-called 'Knightian' uncertainty has gained increased attraction in shaping theoretical and empirical research in finance, given the limitations of the mainstream view in capturing the key elements of the reality.

The uncertainty prevailing in a financial system refers to a complex system in which the overall effect of a single event cannot be modelled statistically, for a combination of factors that are also likely to happen simultaneously (non-linearity, fat tails, second-order uncertainty, random correlation matrixes, contagion, etc.). Combined with the number of possible events, these factors do not allow a statistical treatment of risks. Rather, the 'heuristcs' becomes the only viable approach to analyse the real world.

Taking decisions may call for simple rules precisely because human beings operate in a complex environment, with limited time and information. Since collecting and processing all the information necessary to take complex decisions is costly, and probabilistically calculating the states of the world in the future is beyond human capacities, heuristics and 'bounded rationality' allow to formulate decision making strategies that ignore part of the information and involve little computation.

Financial regulation that is too complex may become a scaling factor for systemic risk. This could result from a combination of several factors: 1) regulators may be led into the illusion of having full control over the entire financial system and its individual components; 2) regulated entities may be provided with strong incentives to engage in regulatory arbitrages and transfer activities and risks outside the regulatory perimeter; 3) excessive complexity in financial regulation tends to produce more rigid frameworks, which are less adaptable to managing a fast-changing external environment, new risks, or, more generally, phenomena not quantifiable in advance ('unknown unknowns').

Moreover, to the extent that regulatory complexity may add to uncertainty (as a minimum, there is uncertainty on the reactions by banks and other financial institutions to the multiple constraints imposed by a complex regulatory framework) it might well be the case that complexity in regulation can increase the level of systemic risk hidden in the financial system.

This paper intends to explore whether and to what extent excessively complex financial regulation might turn out to be costly and cumbersome, as well as sub-optimal for crisis prevention. To this end, I study the regulatory framework developed over the last decades, and discuss the adequacy and the effectiveness of the regulatory response to the global financial crisis (GFC) of 2007-2010. In doing so, I concentrate my attention mainly to banking regulation.

The regulatory pendulum involving different degrees of complexity and/or simplicity in the regulations affecting the international banking system is studied with reference to the sequence of Accords finalized by the Basel Committee on Banking Supervision (BCBS) over the years, starting in 1988. In this context, the issue of complexity derives mainly from banks' use of internal models for calculating capital requirements, and from the widening of the regulatory coverage of risks over time.

Internal models have been given responsibility for significant drawbacks, which may have determined an underestimation of risks in banks' balance sheet. Explanations for this outcome stem from the insufficient consideration of model risk and the excessive complexity embedded in the regulatory framework. However, regulatory complexity is not limited to the measurement of risks. Considering the several Basel Accords, a very complex system of core and non-core capital instruments has progressively emerged, with different capability to absorb losses in both on-going and gone-concern situations.

The final Basel III Accord recognizes the need for simple models and simpler regulatory rules and practices. It is by no means simple in itself, of course; but it does contain comparatively simple backstops to avoid some of the pitfalls of complexity. It is important to outline that regulators are confronted with a trade-off: simple rules are transparent, robust to model risk and more difficult to 'game', but they may fail to measure risks adequately; complex rules may be risk-sensitive, but they are more likely to determine model failures. Furthermore, both are subject to the Lucas critique, since banks and markets adapt to the rules, and this makes the task of regulators very hard.

The GFC has forced central banks and regulating authorities to reconsider the scale of systemic risk and its contagion mechanisms, triggering a severe revision of financial regulation. The regulatory regime that has emerged after the GFC is a multi-layered system with a high number of constraints at play. The underlying economic reasons for this regime shift stem from the existence of a number of regulatory failures and economic externalities, which became particularly evident during the GFC.

This framework with multiple metrics is more robust, as each measure offsets the potential shortcomings and adverse incentives connected to the others. It is fair to say that the regulatory reforms finalized after the GFC have allowed the international banking system to significantly increase its solvency and liquidity conditions, thus enhancing its resilience. This was demonstrated also by the system's response to the COVID-19 emergency situation.

However, the density and complexity of the new regime has raised some concerns, in particular since excessive regulatory complexity may create barriers to entry for new comers, limiting or even impeding competition and innovation in the financial system. At the same time, the burden imposed on the regulated entities encourages the transfer of risks outside the regulatory perimeter, thus amplifying systemic risk, also as a result of the sequencing approach adopted within the post-GFC regulatory repair (i.e., dealing first with banks). Complex regulatory requirements may create a situation where supervision turns out to be a mechanic tick-box exercise, rather than a comprehensive assessment of the contribution of each individual financial entity to systemic risk.

The central idea of this research is that the distinction between risk and uncertainty is crucial for decision-making and should be applied to financial regulation to a wider extent. Since modern finance is characterised by uncertainty (rather than risk), less complex rules could be given greater consideration. Rebalancing regulation towards simplicity may produce Pareto-improving solutions, and encourage better decision making by both authorities and regulated entities.

It is important to underline that addressing systemic risk in a complex financial system should not entail the replacement of overly complex rules with overly simple or less stringent regulations. Even if simple rules can be attractive, they cannot be considered a panacea or a supervisory goal per se. There are many instances - even in the post-GFC reforms - where simple rules would not have helped in reducing regulatory complexity (e.g., the various proposals on bank structural reform, or the calculating methods envisaged for a 'simple metrics', as the leverage ratio, and the regulatory framework in the field of resolution). Moreover, apparently simple definitions have shown a tendency to evolve into regulations that are too complex to implement and enforce (e.g., market making, proprietary trading, and living wills).

A reasonable solution would be to reduce the complexity that is deemed unnecessary. This objective would entail at least: 1) for regulators, an increased capacity to address unknown contingencies in a flexible way, possibly recalibrating a few basic (and easy to manage) tools, and

adopting (and implementing) policy responses in a smooth and timely way; 2) for regulated entities, reducing incentives to game the system and to move risks outside the regulatory perimeter, as well as compliance costs.

The real (and difficult) challenge would be to define criteria and methods to assess the degree of unnecessary complexity in regulation. To this end, this paper proposes some options affecting the content of the rules, the regulatory policy mix for certain financial sectors, as well as the rulemaking process.

- First, a greater degree of proportionality in rule-making would allow to more effectively ensure that the cost of regulation is commensurate to the size and riskiness of banks (and other financial institutions). Stable, simple and fully implemented rules can make significant progress towards this target. However, a careful balance should be struck in the design of proportionality, which should be linked to the riskiness of banks' assets and not produce a reduction in liquidity and capital requirements. Regulators should not overlook the possible accumulation of risks in many smaller institutions that could trigger systemic concerns (too-many-to-fail).
- Second, given the recent evolution of the international financial system, entity- and activity-based regulations should be seen as complementary, especially in some areas (e.g., non-bank financial intermediation, fintech) requiring a consistent treatment of risks. Both approaches should be seen as essential components of an integrated strategy to effectively regulate new and emerging forms of systemic risk. This would contribute to avoid regulatory arbitrage and the transfer of risks outside the regulatory perimeter, while reducing complexity, especially in jurisdictions with a high level of institutional fragmentation (e.g., the US and the EU).
- Third, a lower degree of complexity could be achieved by modifying the 'rules' governing the rule-making process in banking (and finance). Especially after the GFC, the substantive difference between the legislative and technical tiers in rule-making has disappeared, adding rigidity and complexity to the system. A model where the first tier is built through principles of general application, and the concrete implementation of these principles is left to regulators, would allow greater flexibility in regulation, so as to ensure a smooth response to future unknowns.

Complexity versus simplicity in financial regulation may well represent a test bench for regulating authorities. In particular, regulators may wish not to be characterized as behaving like the Isaiah Berlin' hedgehog, "who knows one big thing", and relates everything to a single central vision, one system (fixed for ever), in terms of which he understands, and decides everything.

Rather, regulators may prefer to be similar to the fox, "who knows many things", and pursues many ends, often unrelated and even mutually contradictory, connected only in some de facto way,

and proves better able to deal with new developments. To behave as the Berlin's fox, regulators would have to adopt the degree of flexibility that is needed to deal with a fast-changing external environment.

2. Introduction (and organization of the paper)

In the last decades the financial system has shown a tendency towards increasing levels of complexity. The essential features of this complexity may refer to: i) an increased variety of typologies of financial intermediaries and agents, showing different business models and governance structures, subject to different regulatory treatments; ii) an augmented supply of financial instruments to meet the needs of the lending and borrowing sectors, negotiated in markets having different organizational and regulatory setups; iii) the diffusion of complex (and often opaque) financial instruments, which has resulted in longer and increasingly diversified intermediation chains; iv) the emergence of large financial institutions operating on a cross-border scale and multiple markets, potentially able to pose a systemic risk in a large number of jurisdictions; v) a higher degree of interconnectedness among financial sectors, which makes increasingly difficult to trace and monitor each participant's network of direct and indirect linkages.

The regulatory response to these developments has been based upon very complex risk measurement tools, and even more complex rulebooks.[2] This pattern has not avoided either systemic meltdowns or specific episodes of crisis.

The regulatory frameworks built in the last decades are theoretically grounded on models of decision making under risk, which assume that the probability distribution of all possible states of the world can be calculated by economic agents. This mainstream view in economics and finance has become dominant, crowding out an alternative theoretical approach, which focused individuals' choices under uncertainty, and brought imperfections in information and knowledge to the centre of the analysis. It is this alternative view that has been attracting renewed attention in more recent years. This approach suggests that too complex regulation is not well suited to cope with the real world, and may have adverse consequences. Excessive complexity in financial regulation tends to result in systems that are less flexible, and therefore less adapt to manage a rapidly changing external environment, new risks or, more in general, phenomena not quantifiable in advance ('unknown unknowns").

[2] Successive episodes of financial crises determined a progressive widening and broadening of the financial safety net, from the lending of last resort of the 19th century onwards, to deposit insurance of the 1930s, to the capital and liquidity support for banks and non-banks after the GFC. Until the end of the Bretton Wood system, increasing implicit support was accompanied with strict financial regulation and restrictions on global capital flows, which contributed to minimize the number of financial crises. This balanced structure was progressively altered as a result of de-regulation starting in the mid of 1970s, which may have contributed to increasing the levels of complexity in the system and in the regulatory approach, and in a higher level of overall fragility.

This paper intends to explore whether, and to what extent, excessively complex financial regulations might turn out to be costly and cumbersome, as well as sub-optimal for the purpose of crisis prevention. I will focus my attention mainly on the regulatory frameworks developed over the last two decades.

This research builds on the distinction between risk and uncertainty, which is crucial for decision-making and should be applied more widely to financial regulation. The argument is that since modern finance is characterised by uncertainty (rather than risk), less complex rules could be given greater consideration. Rebalancing regulation towards simplicity may improve decision making of both authorities and regulated entities. However, addressing systemic risk in a complex financial system should not entail replacing overly complex rules with overly simple or less stringent regulations. Neither very complex nor very simple rules or less rigorous approaches to supervision are able to address systemic risk in a complex financial system subject to uncertainty.

A reasonable solution would be to reduce the complexity that is assessed unnecessary. This is no doubt a difficult task. Some options could be worth exploring in this direction to enhance the capability of regulation to respond more smoothly and quickly to new risks.

For example, greater and more effective proportionality in rulebooks could achieve the objective to more properly relate the cost of regulation to the riskiness of the affected entity/externality. However, regulators should not overlook the possible accumulation of risks in many smaller institutions that could trigger systemic concerns. Activity-based regulation could be considered as complementing entity-based approaches, so as to ensure a consistent treatment of new risks across the system. A lower degree of complexity could be pursued through a less rigid approach to the 'rules' governing the rulemaking process, especially in jurisdictions presenting high levels of institutional fragmentation (e.g. the US and the EU).

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This paper is organized as follows: **paragraph 3** provides the theoretical foundations of two economic concepts that are at the centre of this paper (risk and uncertainty), examining the different approaches to risk modelling: those based upon rational choices, those based upon Knightian uncertainty, grounded in heuristics and bounded rationality; **paragraph 4** reviews the channels through which uncertainty and complexity add to systemic risk (uncertainty hedging, bank runs, network externalities, and asset fire sales); **paragraph 5** studies the emergence after the GFC of a multi-constraint regulatory framework, with its associated benefits and costs; **paragraph 6** reviews the regulatory pendulum between complexity and simplicity in international banking regulation, as defined in the Basel Accords; **paragraph 7** underlines the case for simpler (but not less stringent) rules. To this end, some possible options are presented in a number of fields (proportionality, activity vs entity-based regulation, rulemaking). **Paragraph 8** concludes**.**

3. The economics of risk and uncertainty

3.1 Rational choices and risk modelling

In economics and finance, risk has a central theoretical importance, since it is linked to the issue of how economic agents decide in general. All decisions involve risk, as they may lead to either a positive or a negative outcome. A risky decision is a decision with a range of possible outcomes with a known probability for the occurrence of each state; otherwise, the probabilities are not known and a decision is to be made under uncertainty.[3]

Modern economics and finance have been shaped for decades by theoretical models of decision-making under risk. This strand of literature stresses the point that there is an objective, measurable risk and assumes that the decision on how to manage risk can be made rationally, with the application of mathematical and statistical tools. This mainstream view mainly derives from the general equilibrium framework of Arrow and Debreu (1954), which had a profound impact on economic science. Formulated in a purely mathematical form, it produces the first rigorous proof of the existence of a market clearing or Walrasian equilibrium.

Its main suggestion is that under certain conditions (perfect competition and demand independence) there exists a set of prices such that aggregate supply will equal to aggregate demand for every commodity. When commodities are specified to be conditional to various (and future) states of the world, the Arrow-Debreu model can combine expectations and uncertainty into the analysis. It assumes that economic agents behave rationally and know the probability distribution of all future states of the world.[4] Rationality in economic behaviour is the sole basis for decision rules, irrespective of any psychological or sociological constraint.[5]

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[3] In this sense, decisions under risk could be considered as a specific case of decisions under uncertainty. If it is not possible to form expectations regarding the probabilities of available alternatives or future events, a decision has to be made under ignorance. Since full knowledge is seldom available and economic theory uses data from the past to estimate future events and to rank their likelihood, the future will at least to some extent remain uncertain. See for these considerations Zinn (2004).

[4] Even before the 1950s, economic theory identified optimal decision making through optimization techniques. In particular, von Neumann and Morgenstern (1944) defined rational choices as those inferred from probabilistic calculation of all explanatory factors and capable to probabilistically weigh all possible future states of the world.

[5] The goal of this paper does not allow to go through a detailed explanation of the Arrow-Debreu model (and of the other theoretical models cited in this paragraph). It is important to recall here that the Arrow-Debreu model has permitted to analyse - within a general equilibrium structure - the overall impact on resource allocation of policy changes in areas such as taxation, tariff and price control. In particular, the general equilibrium framework has served in: i) shaping the various capital asset-pricing models (CAPMs); ii) explaining high equity risk premiums/low risk free returns during normal/adverse conditions in financial markets; iii)

On the same line of reasoning, the theory of portfolio allocation, as explained in Markowitz (1952) and Merton (1969), assumes that decision-making is grounded upon rational agents, who take optimal choices, since they are in a position to measure all relevant factors and are able to perfectly price, trade, securitise, and hedge risks arising from markets. Together, these models have helped in explaining rationality in real (consumption, and investment) and financial (asset pricing and portfolio allocation) choices. Accordingly, decisions in finance have been modelled based on the assumption of normal distributions, which describe the world through a bell-shaped curve going symmetrically around a mean (Black and Scholes, 1973), and further supporting the principle of risk being correctly knowable and quantifiable.[6]

The underlying assumption of these models can be derived from the rational expectations hypothesis, developed since Muth (1961), according to which information may be acquired at a cost close to zero, and economic agents have cognitive capabilities to measure - in probabilistic terms - all future outcomes.[7] This hypothesis describes a situation in which the agents' average subjective probabilities about the distribution of the relevant variables are equal to the conditional probabilities in the 'true' model of the economy, making optimal use of all the available information, the deviations from perfect foresight being only due to some random noise (Visco and Zevi, 2020).

These models imply that the availability and use of more information always bring to better decisions and more effectiveness. Based on these theoretical premises, models and tools developed for decision-makers have required higher and higher degrees of precision and complexity, underpinned by rulebooks showing increasing levels of complexity. Faced with the difficulty to model correctly the real world, the economic profession has chosen to add complexity to complexity, in the attempt to define the right distribution of events and make models more realistic.[8]

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providing patterns of corporate financing and governance; iv) explaining the conditions of irrelevance of a firm's financial structure for determining the value of a financial claim or of the firm itself, under the Modigliani-Miller Theorem. Finally, in economic literature several contributions stress the importance of the relations of the theorems of welfare economics to the Arrow-Debreu model. For an extensive overview of the impact of Arrow-Debreu on modern economic thought, see Duffie and Sonnenschein (1989).

[6] According to Aikman et al. (2014), this assumption of normality has resulted in a huge under-pricing of tail events. When tail events materialize, as it has been the case in 2007 with the GFC, the cost of ignoring uncertainty may become high and determine large asset price adjustments. .

[7] For these implications and applications of rational expectations models, see Aldane and Madouros (2012).

[8] Derman and Wilmott (2009) report that in the financial industry, most managers are not in a position to fully understand the models they dispose of for their everyday financial decisions. This is also because the mathematical and engineering knowledge embedded in such models can be 'managed' only by super-experts – hired especially for such a job – who hardly know the difference between the real functioning of financial markets and their models.

3.2 Knightian uncertainty, heuristics and bounded rationality

Contrary to these approaches, a number of economists of the past (for example, Knight, Keynes, Hayek, Simon, Friedman, belonging to different schools of economic thought) placed imperfections in information and knowledge at the centre of their analysis and pointed out that uncertainty, rather than measurable risk, is the normal context of decision-making (Hansen and Sargent, 2007). [9] According to these authors, assigning (and knowing) probabilities to future circumstances in an economic or financial system can be particularly difficult, especially for rare, high impact events ('black swans'), such as financial crises, which typically occur at very irregular intervals and bear distinctive features that cannot be modelled ex ante. This difficulty can be exacerbated because the system can be very sensitive to small changes in initial conditions, leading to very different outcomes (Gai et al., 2011).

The complexity of modern finance, characterized by the high interconnected nature of financial linkages among institutions and markets, may imply that risks spread out through the entire system via a number of channels not susceptible of being measured. Moreover, financial systems tend to be highly un-predicable because of the role played by human beliefs about the past, the present and the future, given that such beliefs tend to change over time, depending upon the conditions in the external environment or the prevailing economic thought. As a result, there may be few, if any, stable parameters in economic or financial models that are able to meet the Lucas critique, in the sense that they cannot be considered as being invariant with respect to changes in policy choices (Lucas, 1976).[10]

[9] I will not go through the details of the theories developed by these economists. For essential references, see: Knight (1921); Keynes (1936); Simon (1956); Simon (1962); Friedman (1960); and Hayek (1974). The main points than can serve against the risk modelling approaches can be found in the Nobel Prize Lecture delivered by von Hayek in 1974, The Pretence of Knowledge. He started admitting that the failure of the economists to guide successful policy decisions was closely connected with their propensity to imitate mechanically and uncritically the procedures of physical sciences. Unlike physics, in the study of complex phenomenon, like economics, all the circumstances which determine the outcome of a process are not fully known or measurable. Applying mathematical methods to phenomenon of 'organized complexity', such as financial markets and systems, would give the illusion that we can use this technique for the determination and prediction of the numerical values of practically all economic magnitudes. This happened in spite of the fact that the modern founders of mathematical economics had no such illusions. Von Hayek, quoting V. Pareto, one of the main representatives of this theory, states that it would be 'absurd' to assume that economists would be able to ascertain all the data and give numerical values to all variables.

[10] Lucas underlined the importance of expectations in economic theory and intertemporal decisions of economic agents. He pointed out that expectations should not be – in general - considered as being independent from changes in the variables that are under observation for a decision by policy-makers. In this context, he drew attention to the impact on expectations of changes in monetary policy choices.

If we are not in a position to perfectly calculate or assign a probability distribution to the future states of the world, we are not dealing with risk, but with 'Knightian' uncertainty. In *Risk, Uncertainty and Profit*, a book published in 1921, F. Knight stated that risk and uncertainty are two different categories, because in the former the distribution of the outcomes of a group of instances is known, while this is not true in the case of uncertainty; uncertainty gets in when not all risks are measurable or even knowable (Knight, 1921); Watkins, 1922). Moving from risk to uncertainty, it can be the case that decision rules based upon the calculation of all relevant factors can underperform if compared with rules based on simple averages or less information. In certain circumstances, uncertainty implies that there could be potential benefits to more simplicity over greater complexity, given the higher degree of flexibility allowed (Kirman, 2010; and Aikman et al., 2014).

Over the years, the so-called 'Knightian' uncertainty has gained increased attraction in shaping theoretical and empirical research in finance, given the limitations of the general equilibrium framework and the rational expectations hypothesis in capturing the elements of the real world.[11] Simon (1955, and 1990) believed that taking decisions may call for simple rules precisely because human beings operate in a complex environment, with limited time and information. This author used the term 'heuristics' to indicate these simple rules: they represent an evolutionary response to the external environment, adopted in the light of the experience, intuition, or common wisdom, which implies a mental process that ignores part of the available information and does not optimize (i.e., it does not involve a computation of a maximum or minimum).

The uncertainty prevailing in a financial system refers to a complex system in which the overall effect of a single event cannot be modelled statistically, for a combination of factors that are also likely to happen simultaneously (non-linearity, fat tails, second-order uncertainty, correlation matrixes, contagion, etc.). Combined with the number of possible events, these factors do not allow a statistical treatment of risks. Rather, the 'heuristics' becomes the only viable approach to analyse the real world.

Relying on 'heuristics' in place of optimizing is called 'satisficing'. As recalled by Visco and Zevi (2020), W. Baumol, in a paper written in 1979 to outline the contribution of H. Simon to economics, stated that the crucial difference (between maximizing and satisficing) is that maximization requires a process of comparison of all the available alternatives, while Simon's satisficing criterion is aimed at pinning down 'the first decision encountered which passes the acceptability test, among those decisions subjectively assessed to be feasible'. The objective is to make inferences, which turn out

[11] See for more details on these approaches, Goodhart (1989), Hansen and Sargent (2010), Haldane and Madouros (2012), and Manheim and Garrabrant (2019).

to be more robust and accurate in many cases.[12] Maximizing is possible only in 'small worlds', where all alternatives, consequences, and probabilities are known with certainty, but not in 'large worlds', where not all is known and surprises can happen, and thus maximization is no longer possible (Savage, 1954).[13]

Simon pointed out that since in most cases identifying and comparing all the possible alternatives is very costly, it should generally be excluded by rational agents. Full (unbounded) rationality and maximization have been complemented (or even replaced) by the so-called 'bounded rationality' (Visco and Zevi, 2020). This term dispenses with the idea that optimization is the essence of rationality, making it possible to address problems for which optimization is not feasible. Accordingly, bounds to information and computation can be explicitly included in the problem to be solved. In this approach, there are two kinds of bounds: those in our minds (e.g., limits in memory) and those in the external world (e.g., noisy, unreliable samples of information). 'Bounded rationality' becomes the study of the cognitive processes that help people to make decisions in 'large worlds' (Simon 1955, and 1990; Gigerenzer, 2010).

Since collecting and processing all the information necessary to take complex decisions is costly, and probabilistically calculating the states of the world in the future is beyond human capacities, heuristics and 'bounded rationality' allow to formulate decision making strategies that ignore part of the information and involve little computation. Heuristics and bounded rationality have been increasingly applied to decision-making processes in a number of fields (neurology, applied medicine, engineering, biology, psychology, sociology, forecasting, management, and behavioural economics).

Recent research has shown that the standard view that a heuristic decision can only be second-best in terms of accuracy (because less effort can never lead to greater accuracy) turns out to be invalid. Gigerenzer and Brighton (2009) show that heuristics can be both more accurate and less

[12] In economics and in cognitive sciences, full (unbounded) rationality is typically used as a methodological tool about how people take decisions. According to this approach, people behave as if they maximized some kind of welfare, by calculating Bayesian probabilities of each consequence and multiplying these by their utilities. Full rationality requires reliable knowledge of all alternative actions, their consequences and the utilities and probabilities of these consequences. Furthermore, it entails determining the best of all existing alternatives (i.e., being able to compute the maximum expectation). See Gigerenzer (2010).

[13] Maximization has been applied to almost every field, whether probabilities are known or not, and this overutilization of the theory has created a number of problems and practical applications. For an extensive review of these issues, see Bennis et al. (2010).

effortful: even though a complex calculus leads to the best outcome in a small world, the same calculus may lead to an outcome inferior to that of a simple heuristic when applied in a large world.[14]

Simple strategies may outperform complex ones also in the field of asset pricing. When investing across N assets, the Merton-Markowitz portfolio strategy would weight by risk and return (Markowitz received the Nobel Prize for his optimal asset allocation method known as mean-variance portfolio). A far simpler strategy would equally weight all assets (i.e., a 1/N rule). In out-of-sample trials, the 1/N rule outperforms complex optimizing alternatives (including Merton-Markowitz). Indeed, Markowitz himself pursued a 1/N, rather than Markowitz, strategy when he had to decide his own investments when he retired (Bower, 2011). Heuristics may perform better precisely because a large part of the information is ignored. As the Markowitz example shows, 1/N strategy in portfolio allocation decisions may produce optimal outcomes given that it ignores all previous information about the performance of investment funds across financial markets.

It has been shown how in some circumstances there are potential benefits to more simplicity over greater complexity.[15] In this context, 'bounded rationality' may explain decisions taken under uncertainty, considering the cost-induced deviations from 'pure' rational settings. Since more information can only be acquired at too-high a price, it could be the case that less may become more. Disregarding information and reducing excessive complexity can help take not only cheaper but also better decisions. The optimal response to a complex environment is often not a fully state-contingent rule; rather it is to simplify and streamline. However, simple rules involve a cost: more than complex ones, they depend upon key factors in the remit of the decision-maker, i.e., experience, capacity, and intellectual formation (Gigerenzer, 2010).

4. Uncertainty, complexity, and systemic risk

4.1 Uncertainty hedging and financial contagion

Uncertainty has potential implications for systemic risk. In this paragraph, I focus the attention on the channels through which uncertainty may make the financial system more fragile and more

[14] For more technical details for comparing complex-vs-simple investment strategies, see DeMiguel at al. (2009). These authors find that, for a sample threshold of N=25, complex rules out-perform simple ones only for sample sizes in in excess of 3000 months (i.e., more than 250 years) of data. Even in such a case, less is more (at least without much more available data).

[15] H. Simon, in his study 'The Architecture of Complexity', derived the criteria for evaluating resilience and evolution of complex systems, in physical, biological and social sciences. He says that even complex systems tend to exhibit a basic simplicity. Systems could be organized in a natural hierarchy; non-hierarchical systems would be deselected over time because of their inefficiency or lack of robustness relative to simpler, hierarchical structures. This would be called as the case of survival of the simplest. See Gai et al. (2011).

exposed to crises. To the extent that regulatory complexity may add to uncertainty (as a minimum, there is uncertainty on the reactions by banks and other financial institutions to the multiple constraints imposed by a complex regulatory framework)[16] it might well be the case that complexity in regulation can increase the level of systemic risk hidden in the financial system (ESRB, 2019).

Financial crises have been often associated to periods of great uncertainty on expected returns on financial and real assets, potentially determining contagion among apparently un-correlated assets and sectors. Recent examples can be derived from the Asian financial crisis (1997), the Russian crisis (1998), the collapse of the Long-Term Capital Management (1998), the GFC (2007-2010). In these cases, negative shocks in relatively small markets have rapidly spread to the entire financial system, raising the issue of what was the trigger event for such contagion.

Building on these cases and on the distinction between risk and uncertainty, some authors develop a theory of systemic risk based upon uncertainty aversion and study the adverse spillovers (i.e., contagion) of a negative shock affecting one asset class to other asset classes not directly impacted by the initial shock.[17] They describe uncertainty aversion as the main driver in decision making and asset pricing in cases in which economic agents have only limited information on the probability distribution of future events.[18] Uncertainty-averse investors may prefer to hold an uncertain asset, provided that they also hold other uncertain assets in their portfolios; in doing so, they perform a sort of 'uncertainty hedging'.[19]

Since uncertainty aversion creates complementarities among investors' behaviour, bad news on one asset class may spread to other asset holdings, so that an (initial) idiosyncratic risk may generate a system-wide shock. In such a model, it is a negative sentiment triggered by a single event that has the potential to produce contagion and a systemic crisis. Uncertainty aversion can be the driver of contagion across otherwise unrelated asset classes. By contrast, in the absence of

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[16] See *infra* para. 5 for an analysis of the multiple-constraint prudential framework developed in response to the GFC.

[17] A non-exhaustive list for this literature could include the following: Acharya et al. (2016); Allen and Gale (2000); Allen et al. (2012); Garleanu et al. (2015); Dicks and Fulghieri (2019); Kodres and Pritsker (2002).

[18] Knightian uncertainty is crucial in the determination of asset prices. Uncertainty may lead to equilibria that are indeterminate; in other words there may exist a continuum of equilibria for given fundamentals. This result makes possible that the price-setting process for a particular equilibrium price is in the hands of the Keynesian animal spirits and this may provoke large volatility in the markets (Epstein and Wang, 1994).

[19] In such a model, investors hold - through banks - risky assets, the returns of which are perceived as being uncertain. By holding a number of uncertain assets, investors can lower their overall exposures to the sources of uncertainty, thus reducing the impact of 'tail risk' on their portfolio. The effect of 'uncertainty hedging' is that investors hold a more favourable probability assessment on the future returns of an uncertain asset (i.e., they become more optimistic) when they also hold a larger portfolio with other uncertain assets. See Dicks and Fulghieri (2019).

uncertainty aversion, idiosyncratic shocks affect only the asset directly involved with no impact on the other asset classes.

Uncertainty can increase the risk of bank runs. Even if uncertainty-averse investors may be less prone to run on individual banks, runs can become systemic and are associated to crashes in the stock market and flight to quality. The essential features of the GFC have been framed within theoretical models that have pointed out the relevance of uncertainty aversion among investors and their interaction with banks trading asset-backed securities (Uhlig, 2010). The presence of uncertainty-averse investors exacerbates the fall of asset prices following a negative shock in one segment of the market (as it was the case with the sub-prime episode in the US). Increasing levels of uncertainty may cause idiosyncratic shocks to spread to other banks or asset classes and become systemic. Negative information on a bank may generate a wealth loss to investors; this may in turn increase investors' risk aversion sufficiently to trigger a run on other banks, even though they are not affected by the shock (Goldstein and Pauzner, 2004).[20]

Such a modelling approach to uncertainty has significant links with other strands of literature, according to which in an uncertain environment, investors' portfolio diversification may generate systemic risk.[21] The portfolios of the non-bank financial institutions (NBFIs) are highly diversified, since they pursue diversification strategies at the global level. However, they are also less diverse across individual investors, with holdings of bonds largely overlapping, implying that global investment funds may represent an important channel for the transmission of financial shocks (Signorini, 2018). Significant levels of asset correlation in the portfolio's allocation decisions of NBFIs can facilitate the transmission of stress events across markets.

The role played by non-bank institutional investors with high liquidity needs (and high exposures to the securitized bonds) has been studied within a transmission mechanism explaining the contagion from the securitized bond market to the seemingly unrelated corporate bond market observed during the crisis. [22] The specific purpose is to study how one asset class (securitized bonds)

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[20] In other models, the mechanism that triggers contagion may refer to: investors trying to rebalance their portfolios exposures to macroeconomic risks across asset classes in their portfolios (Kodres and Pritsker, 2002); the excessive portfolio rebalancing after a shock (Garleanu et al., 2015); a deterioration of investors' probability assessment on future returns in one asset class that leads to worsening expectations of future returns in other asset classes (Dicks and Fulghieri, 2019).

[21] Since the paper by Allen and Gale (2000), part of the literature has identified the structure of the interbank market as the key driver of contagion in the banking system.

[22] See Manconi et al. (2012). The evidence collected in this paper shows how in the pre-crisis years institutional investors (insurers, pension funds, asset managers, broker-dealers) with large liquidity needs heavily invested in the markets for securitized bonds (especially in the AAA-rated segment). These assets were considered to be safer and more liquid with respect to corporate bonds, which were assessed as depending more on the

in a situation of increasing uncertainty about market conditions impacts the portfolio decisions of institutional investors holding a variety of other asset classes. This study derives a transmission mechanism based on the effects of liquidity shocks on open-ended institutional investors investing in securitized bonds. When the sub-prime mortgage crisis caused the collapse of the securitized assets markets, in order to face their redemption claims, investment funds did not sell massively the securitized bonds in their portfolios that had become illiquid, but instead reduced sharply their holdings of corporate bonds. This was because investment funds were reluctant to sell the more illiquid assets and book losses at fire sales prices.

4.2 Endogenous complexity and fire sales

Modern financial crises tend to generate a large amount of uncertainty. A central explanation of this uncertainty stems from the complexity of the linkages among financial institutions (especially banks), which can be considered as the driving force of the crisis and its magnitude, as it was the case for the GFC.[23] Endogenous complexity refers to the uncertainty banks face if they are exposed to a large network of credit ties (cross-exposures) among financial intermediaries, and may have an impact on systemic risk.[24]

The relationship between the structure of a financial network and the extent of contagion has been extensively examined in literature. Some authors, for example, Allen and Gale (2000), and Freixas et al. (2000), pointed out that a more interconnected system has the potential to enhance financial resilience, since the losses of a failed bank are spread among a high number of creditors, thus reducing the scope for contagion. In this case, a more diversified pattern of interbank liabilities may lead to a less fragile system (this configuration holds more in the case of relatively small shocks).

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external economic environment, and as such suffering from higher credit risk. In the period 1998-2007 the holdings of securitized bonds held by these institutional investors increased fourfold to nearly $2 trillion.

[23] Uncertainty and complexity have been key drivers for asset fire sales and market crashes during the GFC. In a testimony to Senate in April 2008 (after the failure of Bearn Stearns), B. Bernanke mentioned that one of the causes of this collapse was in the participation of this institution to a wide range of markets, within an extremely complex and interconnected web of linkages with thousands of counterparties. This had led to a chaotic unwinding of positions, which had cast doubts on the financial health of these counterparties. This assessment would have been repeated few months later with Lehman Brothers. See Bernanke (2008).

[24] Caballero and Simsek (2013) show that banks have only local knowledge of cross-exposures; they understand their own exposures, but they are increasingly uncertain about the cross-exposures of banks that are far from themselves, although belonging to the same network. During normal times, banks only need to ascertain the financial position of their direct counterparties. If a liquidity shock hits part of the network, banks become uncertain about cross-exposures; in particular, they now need to understand the financial health of the counterparties of their own counterparties (and their counterparties).

Others have suggested that more interconnections may act as a destabilizing systemic factor, due to the presence of more bank's counterparties. In such models, which treat interbank contagion as an epidemic, the likelihood of a systemic crisis increases with the number of counterparties. In a situation of stress, a domino effect can be generated from the difficulty banks may encounter in assessing their own solvency, given that they suddenly need to take into account the financial health of a larger number of counterparties.[25]

This uncertainty, stemming from the complexity of the financial network itself, has the potential to amplify banks' perceived counterparty risk, and makes even healthy banks become unwilling to buy risky assets, determining negative externalities across markets. In the case of a large liquidity shock, larger domino effects become possible: in the secondary markets, buyers (i.e., other banks in the network) tend to take a precautionary stance to protect themselves, hoarding liquidity and – in the extreme - turning into sellers. The price of legacy assets (i.e., the assets that banks in distress tend to sell to address the initial liquidity shock) goes to fire sale levels, reinforcing the collapse of asset prices. This may determine more banks' failures and even larger domino effects.[26]

An extensive literature outlines the possibility of network failures and contagion in financial markets. Many of these contributions highlight the mechanisms through which solvency and liquidity shocks may generate fire sales for the banks belonging to the network. These features are taken as the explaining factors for the rise in banks' uncertainty and for the effect of this uncertainty on banks' prudential actions.[27] Since banks belonging to the network and that are close to the original distressed bank have an incentive to misreport their distance, preventing the aggregation of information, the objective of increase information and transparency should be fully in the objective function of regulators.

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[25] For example, Allen at al. (2012) argue that the pattern of asset commonalities between different banks determines the extent of information contagion and hence the probability of systemic crises. Gai et al. (2011) study a model of interbank lending with unsecured claims. They show that greater complexity and concentration in the financial network may amplify financial fragility overall. See Allen and Babus (2008) for a more in-depth review of these strands of literature.

[26] The structure of these networks can affect the capacity of regulators to assess the level of systemic risk. Roukny et al. (2016) develop a model to compute the individual and systemic probability of default in a system of banks connected in a network of credit contracts and exposed to external shocks. They find that even in the presence of complete knowledge, it is possible to derive conditions for the emergence of multiple equilibria in the network. Multiple equilibria give rise to uncertainty in the determination of the default probability. This uncertainty can affect the estimation of systemic risk in terms of expected losses.

[27] Brunnermeier and Sannikov (2012) show that exogenous uncertainty is amplified in a fire sale episode, because price uncertainty increases buyers' balance sheet uncertainty, which in turn feeds back into price uncertainty. Dang et al. (2010) indicate that that uncertainty and asymmetric information in credit markets increases during crises because debt contracts become information sensitive.

Endogenous complexity in financial markets may support policy interventions that are aimed at mitigating domino effects during crises (e.g., bailing-out distressed banks or asset-purchase programs), as well as those intended to reduce network uncertainty in good times (e.g., public guarantees on banks' liabilities or assets). In addition, endogenous complexity also supports pre-emptive measures to simplify the structure of financial networks and increase their level of transparency (e.g., stress testing, collecting and publishing data on OTC transactions, or moving them to regulated exchanges, living wills) (Caballero and Simsek, 2013).

In the modern financial systems, the collective behaviour of institutional investors can lead to undue amplifications of market volatility. During downturns, institutional investors entering a situation of financial stress may turn into asset 'fire sales', and these temporary price effects may be amplified, with huge effects on the conditions of markets' liquidity. In this respect, one of the key lessons from the GFC has outlined the role of asset 'fire sales' in aggravating the fragility of the entire financial system.[28] When a fire sale by a financial entity leads to a substantial reduction in the price of an asset, similar assets held in the portfolios of other market participants tend to follow the same declining pattern, with the potential to widen the areas of distress, thus producing further fire sales of assets (also of different nature). This self-reinforcing process can lead to downward spirals in asset prices and net worth of financial institutions raising risk at an aggregate level.

Fire sales of securities have much broader effects than fire sales of real assets, because NBFIs show balance sheets with high vulnerability to an unexpected stop in short-term financing. In the years prior to the GFC, investment funds had financed their activities through short-term liabilities, and were typically heavily leveraged. Such funding requires a renewal process on a continuous time basis. This extreme vulnerability can lead to self-reinforcing and massive liquidation of assets in the case of adverse market conditions (and this precisely occurred in the GFC).

These results indicate that there is a powerful feedback effect between contagion, fire sales and complexity in the financial system. A higher degree of complexity in the structure of banking

[28] Many explanations of the causes of the GFC stressed the role of an initial shock occurred in a particular market (housing property in the US) in generating losses for leveraged financial institutions, including banks. Because of the need to reduce losses, a wide scale deleveraging in these markets produced fire sales of assets. Others point towards the fact that when other market participants have to value their assets at market prices that have become very low for an initial sale, this first sale has determined a cascade of fire sales of assets, which created increasing losses for a large number of financial institutions. In describing the role of the Federal Reserve, it is emphasized that its purchase of the disposed assets permitted an orderly management of the withdrawals from the MMFs industry, preventing massive liquidations of assets at depressed prices, thus stabilizing the system. See for these analyses Carlson et al. (2009), and Pozsar et al. (2013). According to IMF estimates, the $500 billion of losses registered on sub-prime mortgages turned into $4 trillion of write-downs on financial assets at global level through the network of the NBFI entities and their funding techniques. See IMF (2009).

networks may produce more severe fire sales, amplify domino effects, and increase banks' counterparty risk. Fragile and complex structures of financial institutions' balance sheets may exacerbate fire sales, even in the case of an idiosyncratic shock, spreading contagion to the system as a whole.

5. Why and how we have regulated finance (after the global financial crisis)

5.1 The benefits of a multi-layer regulation

The GFC has forced central banks and regulators to reconsider the scale of systemic risk and its contagion mechanism, triggering a fundamental revision of financial regulation. The wave of reforms finalized after the GFC has resulted in a regulatory framework that cannot be seen as a mere recalibration of the previous rules; rather, it represents a shift towards a multi-layered system with a higher number of constraints at play (Haldane, 2015).[29]

The underlying economic reasons for this change are connected to the existence of regulatory failures coupled with externalities/frictions in the financial system, particularly those that had arisen prior and during the GFC that have been either ignored or improperly dealt with in the (then) existing regulation (Carney, 2018). The overall policy response to the GFC has included more stringent risk management tools, more regulation on key elements of finance and banking, and an increased number of regulators.

It has been recognized that a regulatory framework mainly centred upon a single measure (i.e., risk-based capital adequacy requirements for banks) may not succeed in dealing with the externalities/frictions stemming from the financial system. Such an approach implicitly would assume that we can make the system safe by simply ensuring that individual banks are safe. This, however, may overlook a fallacy of composition: in trying to make themselves safer, banks and other highly leveraged institutions may behave in a way that collectively undermines the entire system.[30] In this

[29] In addition to the risk-weighted capital ratio, the post-crisis framework also includes a leverage ratio, large exposure limits, and two liquidity standards (i.e., the Liquidity Coverage Ratio and the Net Stable Funding Ratio). Supervisory stress test plays an increasingly important role across jurisdictions. For more references see *infra* para. 6.

[30] For example, while selling an asset when its perceived risk increases can be a prudent response from the perspective of an individual bank, the same does not hold if many banks do the same. The asset price will collapse, forcing institutions to take yet further steps to rectify the situation. Such response by banks may lead to generalized declines in asset prices, and to enhanced correlations and volatility in asset markets. Forced sales of assets drive up measured risks and, invariably, booms turn to busts. At that point, markets (and regulators) require more capital for banks, thus aggravating the situation. For these considerations, see Brunnermeier et al. (2009).

way, risk becomes endogenous to bank behaviour, and the increasing role of markets in the allocation of savings to investments intensifies such endogeneity.

This is why after the GFC, micro-prudential regulation, centred upon the response of an individual bank to exogenous risk, has been complemented by macro-prudential regulation, which incorporates endogenous risk and takes into account the systemic importance of individual institutions, through factors such as their size, leverage, and interconnectedness with the rest of the system (ESRB, 2016; and Hellwig, 2018).

The regulatory toolkit has been revised (and widened) in order to respond to the growing role of the non-bank financial intermediation (NBFI) sector, in financing real economic sectors, and in managing financial assets. The increased importance of NBFI has determined higher degrees of interconnectedness among financial sectors and longer and more complex chains of intermediation (Visco, 2013, and FSB, 2020). A key lesson emerging from the GFC is that to be able to survive periods of stress in the future, non-bank based intermediation should be re-designed with less leverage, less risky assets and less maturity transformations (FSB, 2013, and 2017).[31] Pro-cyclicality, herding behaviour and highly correlated assets create the scope for bubbles and high volatility, even when these events occur away from the underlying economic fundamentals (Trapanese, 2021).[32] Because of this, regulators now pay greater attention to the effects on the financial system (and on the real economy) of the collective actions of the NBFIs, i.e. they are adopting a macro-prudential approach (Signorini, 2018).

The shift of credit intermediation towards markets has made market liquidity an essential factor to ensure resilience. In the light of the experience of the GFC, the markets' liquidity has increasingly been considered as having the properties of a scarce public good.[33] This can give rise to the possibility that the market on its own is unable to meet all liquidity needs, especially in time of stress, with the potential to generate a severe liquidity squeeze.[34] These externalities, coupled with

[31] The role of the NBFI sector during the GFC brought to light the large tail risks hidden in the system. This under-pricing of tail risks fuelled the credit boom, but in the end, the collapse of the NBFI sector spread distress across the whole financial system and into the real economy. The operations of the NBFIs were interconnected with traditional banks and insurance companies, creating new channels for contagion and systemic risk.

[32] These externalities have the potential to reduce the liquidity and the capital positions of the other financial institutions and are likely to be aggravated depending on the size of the defaulting entity and on the level of concentration in the asset management markets.

[33] Haldane (2015) argues that these properties can be of relevance because the collective benefits of market liquidity in ensuring the smooth functioning of financial markets outweighs the individual benefits from its provision.

[34] This liquidity externality may prompt asset fire sales by banks and financial institutions, pushing down prices and tightening funding conditions even further, or determine a sudden halt in credit provision.

correlated asset prices movements, may aggravate the damages to the real economy (credit crunch) in a pro-cyclical loop (Brunnermeier, 2009; Brunnermeier and Pedersen, 2009; Aikman et al., 2014).[35]

Highly interconnected financial systems are also subject to network externalities, where negative shocks may propagate faster, given the high number of banks and other financial institutions that are contractually linked to one another and hence susceptible to counterparty risk. Prior and during the GFC, the more interlinked network structure of the financial system was no longer a guarantee for stability (Haldane, 2009; Acemoglu et al., 2015). Rather, when large shocks materialized, highly diversified lending patterns facilitated the spread of financial distress and solvency problems from one institution to the rest of the system. Moreover, given this network structure, the increased reliance upon certain types of transactions (i.e., securitization in the pre-GFC years) has enabled credit expansion through greater leverage, driving down lending standards and increasing fragility (Shin, 2008, and 2009).

Market distortions can also come from policy interventions. For example, many authors have highlighted the fact that support measures (in the field of liquidity or capital) may have increased moral hazard, especially in the pre-GFC years, for banks or other financial institutions considered to be too-big-to-fail (Farhi and Tirole, 2012; Alfonso et al., 2014). Others have argued that the role of internal models for capital requirements had a role in contributing to regulatory-induced market failures, for example in providing incentives to game the risk-sensitive regulatory system, adjusting weights so as to lower the regulatory burden for the largest banks (Haldane, 2015).[36]

The merits of the post-GFC regulatory reforms in addressing the externalities and frictions of the financial system identified during the GFC are widely recognized. It is fair to say that the regulatory reforms finalized so far have allowed the international banking system to significantly increase its solvency and liquidity conditions, thus enhancing markets' expectations regarding its resilience and capacity to withstand unexpected shocks, while continuing to support the economy, as it proved to be the case with the COVID-19 emergency situation. A recent analysis shows that the real economic sectors (firms, and households) would have borne grater costs in the absence of the

[35] Cifuentes et al. (2005) show that prudential regulation (in the form of minimum capital requirement ratios or other solvency constraints) when combined with mark-to-market rules can sometimes generate undesirable spill-over effects. Marking to market enhances transparency but it may introduce a potential channel of contagion and may become an important source of systemic risk. Liquidity requirements can mitigate contagion, and can play a role similar to capital buffers in curtailing systemic failure. During periods of financial distress, when risk appetite is very low, liquidity requirements may be more effective than capital buffers in forestalling systemic effects.

[36] For more details on internal models, see *infra* para. 6.

post-GFC regulatory reforms, and that the jurisdictions most affected by the shock have been those where the implementation timeline of these reforms had suffered more delays (BCBS, 2021).

The multiple-constraint framework that has emerged after the GFC is more robust, as each measure offsets the potential shortcomings and adverse incentives of the others.[37] The adoption of such a toolbox relies also upon the underpinning that - given the limitations to our knowledge of the external environment – it would be preferable to rely upon a number of 'imperfect' tools rather than a single tool, whose definition and implementation could never fully achieve perfection.

The overall policy response to these externalities/frictions seems to be the materialization of the Tinbergen's rule, which states that to achieve the desired levels of a certain number of objectives for the policy maker needs to control an equal number of tools (Tinbergen, 1952). In the post-GFC regulatory framework, as many regulatory instruments have been defined as the number of externalities to be dealt with. Limiting the analysis to banks (i.e., not considering markets, infrastructures, non-bank financial entities) and to the most significant externalities, as outlined before, one can refer to the following tools: liquidity standards, leverage ratio, revised risk-based capital requirements (including the systemic capital surcharge), total loss absorbing capacity requirements, capital conservation and counter-cyclical buffers, and resolution regimes.[38] In other words, the post-GFC regulatory repair has proceed on a friction-by-friction (and rule-by-rule) basis.

5.2 The associated costs

The density and complexity of new regime has raised some concerns. Financial regulation that is too complex may become a scaling factor for systemic risk. This could result from a combination of several factors: 1) regulators may be led into the illusion of having full control over the entire financial system and its individual components; 2) regulated entities may be provided with strong incentives to engage in regulatory arbitrages and transfer activities and risks outside the regulatory perimeter; 3) excessive complexity in financial regulation tends to produce more rigid frameworks, which are less adaptable to managing a fast-changing external environment, new risks, or, more generally, phenomena not quantifiable in advance ('unknown unknowns').[39]

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[37] For example, the leverage ratio provides an absolute cap on leverage, but, by itself, could incentivise banks to increase their holdings of higher-risk assets. The risk-weighted framework compensates for this, as it constrains banks that materially increase their risk profile without any commensurate regulatory capital to fund their balance sheets. The liquidity standards require banks to maintain a prudent buffer of high-quality liquid assets and restrict the degree of maturity mismatch. See for these considerations, Ingves (2016).

[38] For an in-depth analysis of the regulatory framework that has been built in the last twenty years (mainly that affecting banks), see *infra* para. 6.

[39] The term 'unknown unknowns' derives from a statement made by the (then) US Secretary of Defense, D. Rumsfeld, in response to a question during a news briefing in February 2002, about the lack of evidence linking

The new framework has entailed a considerably more complex rulebook. Increased complexity derives not only from the mere content of the rules, but also from the process that has been defined to adopt the rulebook.

The post-GFC regulatory repair has been internationally coordinated and finalized, under the aegis of the G20, by the Financial Stability Board (FSB), the Basel Committee on Banking Supervision (BCBS), and the other 'sectoral' international standard-setting bodies. These rules and standards have a non-statutory nature. Their effectiveness is built upon the reputation of the international committees, as well as the pressure exercised by peers and markets. They need an enforcement and implementation process to be defined at the level of each participating jurisdiction, based upon their own legislative/regulatory context. And each institutional step has the potential to add to complexity.

This is one of the factors explaining why the post-GFC regulatory texts have increased in length and complexity (and opacity) by several orders of magnitude. Viewed over a longer time horizon, for example comparing the regulatory response to the crisis of the 1930s and to the GFC, [40] this pattern is even more impressive, especially in some jurisdictions. This complexity may be exacerbated if the analysis is pushed to include the several layers of financial architecture (and actors) that in some jurisdictions are needed to finalize the legislative and regulatory process (e.g., in the EU). Accordingly, the number of human resources devoted to financial regulation within national and international regulatory authorities, and compliance costs on banks and financial institutions, have scaled up dramatically.

Regulatory complexity may produce a situation where supervision turns to be a mechanic tick-box exercise, rather than a comprehensive assessment of the contribution of each individual financial entity to systemic risk. Moreover, this excessive regulatory complexity may create barriers to entry for new comers, thus limiting or even impeding competition and innovation in the financial system, and at the same time it may encourage the transfer of risks outside the regulatory perimeter, thus amplifying systemic risk (FSB, 2021). While there is a widespread consensus on the effectiveness of

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the government of Iraq with the supply of weapons of mass destruction to terrorist groups. This statement brought much public attention and fame to the concepts of 'known knowns', 'known unknowns', and 'unknown unknowns', which were, until then, confined to the theoretical debated within limited circles of economists, sociologists, and medical scientists.

[40] Haldan and Madouros (2012) compare the legislative response in the US to the Great Depression (1930s) and to the Great Recession (2000s). They find that the Glass-Steagall Act of 1933 ran to 37 pages, while the Dodd-Frank Act of 2010 ran to 848 pages (more than 20 times). For implementation, the Dodd-Frank Act requires more than 400 pieces of detailed regulation by a variety of US regulatory agencies. They estimate that - once completed - the Dodd-Frank Act induced regulation could comprise more than 30.000 pages. Overall, this could imply a rulebook a thousand times larger than the one finalized during the 1930s.

each individual tool to address the related externality, the overall impact of this multi-constraint regulatory framework on market dynamics, intermediaries' behaviours, business models, and financial stability still needs to be fully assessed (Ingves, 2018; BCBS, 2021a).

6. Complexity versus simplicity in the Basel Accords: a case study across time

6.1 The roots of complexity

The evolution of financial regulation has been often characterized as displaying a cyclical pattern.[41] The regulatory pendulum - involving a variety of movements entailing different, and sometimes even overlapping, degrees of complexity and/or simplicity in the regulations affecting the international banking system - can be studied with reference to the regulatory frameworks finalized by the BCBS over the years, since 1988.[42] These movements crucially depend upon the interplay of a number of key factors, which can be defined in terms of the prevailing economic thought, the approaches adopted by supervisors, and the interests pursued by banks.

The first Basel Accord (the so-called Basel I) on the calculation of capital requirements against (only) credit risk, adopted in 1988 and implemented in 1992, marked the move from the 'structural' (based upon authorizations) to 'prudential' (centred upon a minimum ratio, 8 per cent, between capital and risk-weighted assets - RWAs) supervision. The framework was kept as simple as possible. It included only few categories of assets or off-balance sheet exposures, weighted according to different categories of relative riskiness, mainly based upon the legal nature of banks' counterparties, and only a limited number of weights was used (BCBS, 1988). [43]

[41] A significant amount of academic research finds that there is a pattern of regulatory changes, which tends to repeat itself during economic cycles. Regulatory policies have the potential to behave pro-cyclically when and if they contribute to credit expansion and overvaluation of assets prices during booms, while increasing credit restrictions and depressing asset values during busts. In the same vein, financial supervision is pro-cyclical when oversight is relaxed during a boom and reinforced during the subsequent bust, with effects on the real economy that, when cumulated, end up reinforcing the underlying trends. The most significant financial crises of the past have occurred after periods during which the prevailing policy approaches had diminished the degree of stringency of financial regulation and supervision with the aim to foster credit to economy. In the end, crises and major regulatory reforms reverse the policy stances previously adopted. As a result, the financial regulatory framework is overhauled and new authorities, with new powers and tools, are established. For an extensive analysis of this issue, see Visco (2013), Dagher (2018), and Trapanese (2020).

[42] In this paragraph I will refer mainly to the following Basel texts: Basel I in 1988; Basel II in 2006; Basel III between 2010 and 2017. The last package contains the core part of the post-GFC regulatory financial repair, including some key features whose implementation is scheduled to be phased in in the years to come.

[43] The weights used were the following: 0 per cent (for cash, or claims on central governments and central banks, denominated and funded in national currency); 0, 10, 20, or 50 per cent (at national discretion) for

The issue of complexity in banking regulation arises mainly (but not only) from the use of internal models to compute capital requirements (Ingves, 2016). The possibility to calculate regulatory capital against credit, market, and operational risks through internal ratings based (IRB) methods (approved by supervisors) was introduced by the BCBS over a decade, between 1996[44] and 2006[45], on the basis of the (then) consensus view, according to which more risk-sensitive approaches would be sufficiently granular to enhance the capture of risk, and to dis-incentivize 'risk shifting' behaviour by banks. It was recognized that under Basel I, risks had not been correctly priced, and banks had a regulatory incentive to retain the exposures with the highest risk on their balance sheets, as these were also likely to offer the highest expected return, given that the costs, in terms of capital, for a riskier asset were the same as for a safer one.

In the academic domain, especially in North-American universities, the foundations of Basel I were not fully accepted. Important contributions in the theory of finance - stemming from economists, such as H. M. Markowitz, M.M. Miller, W. F. Sharpe, R.C. Merton, and M. Scholes (all Nobel Prize winners) - had been explaining for years the possibility to measure and model risks through more sophisticated methods, well beyond the over-simplified approaches embedded in Basel I (Kim and Santomero, 1988, and Rochet, 1992). These approaches to finance and risk modelling, as explained in more details in paragraph 3 above, have represented the rational for the Basel II Accord (De Bonis and Trapanese, 2022). It is interestingly to note here that US regulators have been more reluctant over the years to implement the Basel II standards in their jurisdiction.

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claims on domestic public sector entities; 20 per cent (for multilateral developments banks, or banks); 50 per cent (for loans fully secured by mortgages); 100 per cent (for claims on the private sector).

[44] In 1996, the BCBS allowed, for the first time, the possible use of banks' proprietary in-house models for the calculation of market risk capital requirements as an alternative to a standardised measurement framework (BCBS, 1995); this is the so-called Market Risk Amendment to the 1988 Capital Accord.

[45] A much more complex system of risk weights was introduced by the BCBS in 2006 for the main drivers of risk to banks' solvency (credit, market, and operational risk). This framework is referred to as Basel II. Banks were allowed, subject to regulators' approval on the basis of quantitative/qualitative criteria, to use their own internal models for calculating capital requirements, under one of the two options, a relatively simpler Foundation Approach, for which key variables were provided by regulators, and an Advanced Approach, in which banks were allowed to make greater use of internal data to estimate a wider range of variables (BCBS, 2006a). Limiting to credit risk, these models provide estimates of variables, such as the probability of default (PD), the loss given default (LGD), and the exposure at default (EAD), to be introduced into a non-linear formula provided by the Basel Accord. Banks lacking the capacity to model these risks were required to use the Standardised Approach (SA), under which capital requirements rely upon external agency ratings. These rules underpinning the calculation of regulatory capital (the so-called Pillar 1) are complemented by two other components, which rely upon the evaluation process of banks' capital adequacy by supervisors (Pillar 2), and market discipline (Pillar 3).

This view was also shared by banks, and contributed to modify approaches/attitudes within the international supervisory community.[46] As a result, the possibility to use internal models to measure risks was increasingly adopted, especially by the largest and most complex banking institutions operating on a global scale (Gerding, 2009). The central point of Basel II was that banks would be better equipped to calculate their own risks than their supervisors and that the advanced approaches would allow, in principle, to align the objective functions of banks and supervisors (an assumption that would soon be disproved by the GFC), reinforcing banks' incentives to adopt better risk management tools, and, in the process, benefiting from lower capital charges.

From the start, however, there was the potential for a systematic distortion in the framework, given that banks' incentives for lowering capital constraints were likely to work more effectively than the other ones. According to Signorini (2017), the first-order incentive for bank model-builders is to save costly equity capital. At that time, regulators saw this issue, and they thought that supervisory validation would work effectively to avoid this outcome. However, granularity, sophistication, and complexity of these models make validation a daunting task. Despite all supervisory activity, in fact, the regulatory risk density of banks' assets came to vary across banks.[47] This distortion would be exacerbated in the case of more advanced (and opaque) internal models, i.e., those tailored for trading activities or other sophisticated financial products (another feature that would be confirmed within a few years by the GFC) (Signorini, 2021).

Basel II implies greater complexity and granularity in the computation of banks' capital requirements, since risk exposures are no longer captured at an asset class level and risk weights are no longer confined to the few buckets envisaged by Basel I.[48] For a large, complex bank's banking book, this may require a very high number of parameters to be calculated and calibrated. Moreover, to turn these values into regulatory capital, the number of parameters increases by another order of magnitude. If we open the door to the calculations needed for the trading book, the overall picture

[46] As to the supervisory community, it is to recall here that when Basel II was under development, the same BCBS had same concerns about the reliability and robustness of these models. There was ample evidence to suggest that the envisaged role of internal models in the regulatory domain could not strike the right balance between simplicity, comparability and risk sensitivity. See for these considerations, Ingves (2015).

[47] Signorini (2017) stresses that there is another crucial drawback in banks' internal models in terms of lack of robustness. Financial risks are not always likely to be treated statistically. Crucially, what seems to work well 95% or even 99% of the times can fail in a crisis.

[48] For example, the capital requirements against a corporate loan under the IRB approach in Basel II require a mathematical formula to be fed with a number of internally estimated parameters, while the standardized approach (SA) applies the risk weight corresponding to the external rating assigned to the exposure or a 100 per cent risk weight (as in Basel I), if the exposure has no external rating (Aikman et al., 2014)

becomes even worse (Haldane, 2011; Haldane and Madouros, 2012).[49] Model complexity and uncertainty, coupled with short series of data, have made calibration difficult and robustness questionable.

Regulatory complexity is not limited to the measurement of risks; it can also be found into the numerator of the capital ratio, i.e., the definition of capital. Considering the several Basel Accords, a very complex system of core and non-core capital instruments (and tiers, and tiers within tiers) has progressively emerged, with different capability to absorb losses. This holds for the capital to be held in both on-going and gone-concern situations, thus adding on the high number of parameters to be calculated to the overall count needed to define banks' solvency position.

This excessive granularity in both the numerator and denominator of the regulatory capital ratio may have an impact on markets' ability to differentiate across banks and may provide significant room for regulatory arbitrage (Haldane, 2011; Le Leslé and Avramova, 2012). Moreover, the over-parameterisation of the internal models can call into question the robustness of the regulatory framework as a whole (Haldane and Madouros, 2012). In addition, the quest for ever greater quantitative precision in measuring risk can be illusory. Even a 'perfect' risk sensitive framework may not deliver the expected results, when left alone into a single-constraint system.[50]

It is still debated whether or not the rules under Basel II could have contributed to the GFC (Cannata and Quagliariello, 2009; Signorini, 2021). If we consider the internal models against credit risk, it is fair to admit that they cannot bear full responsibility for what happened, since Basel II was just in the very early stages of implementation, and in most key jurisdictions the Basel II framework had not even been implemented. This does not hold for the internal models for market risks, which were in force since 1996. In this case, the move towards not conservatively calibrated measurement models contributed to exacerbate the impact of the GFC. Especially in the case of the largest (US)

[49] The relative complexity of the IRB approach can be also measured if we consider the length of the texts devoted to its description in the Basel Accords compared with the space devoted to the SA approach. The same holds if we consider the implementation acts to be adopted at the national level. For example, in the EU, this is true for the relative space (in terms of articles and pages) assigned in the Capital Requirements Directives and Regulations. This assessment is even more confirmed, if we take into account the relative number of the technical standards of the European Banking Authority (EBA) needed to implement the two approaches. Similar patterns occur if we move from the credit to the market risk framework.

[50] The (then) Chairman of the BCBS S. Ingves pointed out in 2015 an interesting similarity between the Swedish royal warship Vasa and the Basel II framework. The Vasa was ordered in 1625 by King Gustav II Adolf of Sweden. It was a very impressive warship, with two gun decks, 64 bronze cannons, and its tallest mast soared to 57 metres. It was the result of a quest for perfection. This perfection was short-lived. The Vasa sank on its maiden voyage, after sailing only 1.300 metres on 10 August 1628. Historians generally agree that the trigger of the Vasa' destiny was the lack of stability and the hull's excessive rigidity. In short, the Vasa was well constructed but incorrectly proportionate. See Ingves (2015).

investment banks, a significant increase in leverage, coupled with large holdings of non-tradable products in their trading books, determined capital requirements that were not able to absorb losses when they materialized (Pilati, 2021).

In any case, it should be recognised that Basel II, to the extent that it allowed significant capital savings to the largest IRB banks, would not have represented the right answer to the problems raised by the GFC (Barbagallo, 2019).

6.2 The post-GFC repair: complexity vs simplicity (and comparability)

The GFC highlighted a number of shortcomings within both the banking system and the regulatory framework. Among these: too much leverage, with insufficient high-quality capital held against banks' assets; excessive credit growth, determined in part by weak underwriting standards and an under-pricing of risks; asymmetric prudential treatment between credit and market risks (those risks that were the direct causes of the GFC); absence of liquidity requirements and of appropriate regimes to guard against the risks connected to large exposures; insufficient capital buffers to mitigate markets' pro-cyclicality. To respond to these drawbacks, the BCBS finalized a first round of the post-GFC regulatory reforms, the so-called Basel III framework, between 2010 and 2014.[51]

Basel III has emerged as a multiple-constraint framework, where these constraints complement one another, delivering a more robust regulatory system. These reforms have been wide-ranging and have had a visible impact in strengthening the resilience of the international banking system (Coen, 2018).[52] However, these benefits have come at a cost: the Basel III framework has not reversed the observed upward trend in complexity, detail, and granularity (Hoenig, 2013).[53]

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[51] The features of the 2010-2014 Basel III framework have been aimed at: improving the quality of regulatory capital, through a greater focus on going-concern loss-absorbing capital (i.e., Common Equity Tier 1); increasing the level of capital requirements, to withstand losses also in times of stress; enhancing risk capture, revising areas of the Basel II that had proved to be miscalibrated, and including global standards for market and counterparty risks, and securitization; adding macro-prudential elements (i.e., counter-cyclical capital buffers, revised large exposure regime, capital surcharge for systemic banks); specifying a minimum leverage ratio, as a complement to the risk-sensitive rules; introducing requirements on excessive liquidity risks and maturity transformation. See the following Basel texts: BCBS (2011); BCBS (2013); and BCBS (2014).

[52] A number of empirical studies points to clear macroeconomic net benefits of higher capital and liquidity requirements (Gambacorta and Shin, 2016).

[53] This trend is reflected in the length of the Basel texts. For example, Basel I was only 28 pages long, while Basel II included 347 pages in the version issued in June 2006. The Basel III framework, covering liquidity, leverage, and risk-based capital requirements, adds up to more than 600 pages. In 2019, the BCBS has finalized a consolidated version of the Basel framework: it counts 1.626 pages (including also the sections related to the Basel core principles) (BCBS, 2019).

This higher degree of complexity is justified only if it increases the capacity of banks to measure upfront risks and thus enhances their resilience against unexpected losses (ESRB, 2019). However, the 2010-2014 Basel III had remained unchanged from Basel II in the way risk is measured, in particular, in the reliance on banks' internal models and the risk weighted approaches (Ingves, 2015).[54] And this notwithstanding the fact that the IRB models seem to have performed sub-optimally since their inception, given that they have not produced outcomes that can be seen as comparable across banks and time.

Several BCBS studies have performed benchmarking exercises and found significant variation in risk-weighted assets across banks for a set of identical hypothetical portfolios, and this variation has been confirmed in all aspects of banks' risk categories; moreover, there seems to have been a decrease over time in risk weights for bank exposures (BCBS, 2016a, 2016b, 2015, 2013b, and 2013d).[55] A second consequence of the introduction of the IRB models has been that similar exposures generate different risk weights, depending on the model adopted by each individual bank (ESRB, 2019). Academic authors pointed out that the observed differences in RWAs for IRB banks can be explained with the discretion that banks are allowed to use when applying risk weights depending upon jurisdictions of incorporation.[56] Overall, this means that the differences observed in the IRB outcomes have tended to be larger than the differences explained only by different risk intensities.

Others have found evidence of a 'strategic' use of IRB models to generate the desired risk weights.[57] More importantly, evidence has been gathered indicating that, instead of the risk-weighted assets behaving pro-cyclically (as one would expect), RWAs remained stable in terms of total assets during the GFC and even decreased (Ledo, 2011). Finally, some evidence suggested that the banks using internal models were charging higher interest rates on their loans, as compared to other banks, while simultaneously applying lower risk weights on them (Behn et al., 2014).

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[54] If internal models are used to set minimum capital requirements, banks may have incentives to underestimate risks. See for these considerations, Ingves (2016).

[55] In the case of large US banks, since 2006, it was found evidence that the adoption of the advanced internal models would have given rise to large reductions in regulatory capital not justified by the improvements in risk measurement standards (Kupiec, 2006).

[56] Le Leslé and Avramova (2012) find that a host of factors drives differences in RWAs outputs between banks and jurisdictions; they refer to the following: banks business model, risk profile, RWAs methodology, and supervisory practices.

[57] Mariathasan and Merrouche (2014) examine a panel of 115 banks from 21 OECD countries and find that the decline in risk-weights is particularly pronounced among weakly capitalized banks, where the legal framework for supervision is weak, and in countries where supervisors oversee a high number of IRB banks. They conclude that part of the reduction in RWAs under the IRB models results from banks' strategic risk-modelling.

Over the years, internal models have been given responsibility for significant drawbacks (e.g., reductions in risk weights, substantial variation in risk-weighted assets for identical portfolios, excessive variability in risk weights across time and across banks), which may have determined an underestimation of risks in banks' balance sheet. Explanations for this outcome stem from the insufficient consideration of model risk (i.e., the risk that internal models produce non accurate results) and the excessive complexity embedded in the regulatory framework.

The final package of regulatory reforms finalized by the BCBS in 2017 contains several amendments addressing complexity in financial regulation, especially in the calculation of RWAs, in order to improve the comparability of banks' capital ratios. These reforms have been built upon the strategic review of the risk-weighted capital framework, performed by the BCBS to achieve a right balance in terms of simplicity, comparability and risk sensitivity. They have been grounded into three broad categories: enhancing the risk sensitivity and robustness of standardized approaches; reviewing the role of internal models in the capital framework; finalizing the design and calibration of the leverage ratio and capital floors (BCBS, 2017).[58] This package has been completed through a 'fundamental' revision of the rules affecting the market risk framework, tailored to reduce excessive complexity and opacity, through more stringent criteria for the use internal models and enhanced risk sensitivity overall (BCBS, 2019a).

Capital requirements for credit exposures to banks, large firms and equity portfolios will no longer be determined by risk weights derived from banks' internal risk models, but instead will use the revised standardized approach, given that for these exposures the use of statistical tools is hampered by the unavailability of a reliable time series of observations.[59] There are also constraints on the use of internal models for certain categories of loans (specialised lending and loans to medium-

[58] In greater details, this package seeks to restore credibility in the calculation of risk-weighted assets (RWAs) and improve the comparability of banks' capital ratios by: enhancing the robustness and risk sensitivity of the standardised approaches for credit risk, credit valuation adjustment (CVA) risk and operational risk; constraining the use of the internal model approaches, by placing limits on certain inputs used to calculate capital requirements under the internal ratings-based (IRB) approach for credit risk and by removing the use of the internal model approaches for CVA risk and for operational risk; introducing a leverage ratio buffer to further limit the leverage of global systemically important banks (G-SIBs); and replacing the existing Basel II output floor with a more robust risk-sensitive floor based on the Committee's revised Basel III standardised approaches (BCBS, 2017).

[59] These rules apply to banks using the advanced IRB models.

sized firms).[60] Moreover, the prudential treatment of operational risk has been deeply revised, and it is no longer possible to calculate such risk through banks' internal models.[61]

Two further changes to the Basel framework also move towards a simplification: the introduction of a non-risk-weighted leverage ratio as a "backstop" (rather than as a substitute) to the risk-weighted approach; the application of "output floors" for banks using internal models that are to be set at 72.5% of the capital requirement that the bank would face under the revised standardised approach. In other words, such a floor would set a limitation to the risk-density reduction that banks can achieve through their own models (Signorini, 2017). Importantly, simpler (and possibly less risk-sensitive) rules under Pillar 1 imply a much greater reliance on Pillar 2 supervisory approaches that involve more subjective risk assessment – more akin to principles-based regulation – with its own complexities (ESRB, 2019).

Overall, the recent reforms of Basel III can be considered as an important step in the direction of a simpler regulatory framework, to the extent they reduce the possibility for banks to use internal models, introduce more constraints to models' parameters, and impose strict limits (or floors) on model outputs, in order to limit excessive variability in their results.[62]

According to Signorini (2017), the final Basel III Accord recognizes the need for simple models and simpler regulatory rules and practices. It is by no means simple in itself, but it does contain comparatively simple backstops to avoid some of the pitfalls of complexity. It is important to outline that regulators are confronted with a trade-off: simple rules are transparent, robust to model risk and more difficult to 'game', but they may fail to measure risks adequately; complex rules may be risk-sensitive, but they are more likely to determine model failures. Furthermore, both are subject to the Lucas critique, since banks and markets adapt to the rules, and this makes the task of the regulators very hard.

[60] This package includes also a number of revisions to enhance the robustness of the standardized approach for credit risk, in to order to define a credible alternative to the risk-sensitive methods and a reliable parameter for the calibration of the output floor.

[61] The issue of governance of internal models could potentially worsen in the near future, through the possible increasing use of risk measurement tools based upon artificial intelligence and machine learning techniques (Signorini, 2021).

[62] Further reforms are advocated to rebalance the Basel framework in the direction of simplicity and comparability (e.g., inverting the hierarchy of solvency rules between risk-weighted capital ratio and leverage, reconsidering the internal scale for the three Basel pillars, and allowing more room for supervisors' discretion). See Haldane and Madouros (2012).

7. Regulation under uncertainty

7.1 The case for simpler (not less stringent) rules

The complexity embedded in the regulatory framework developed so far may not represent the optimal response to the uncertainty prevailing in the markets and to the externalities/frictions resulting from the GFC (ESRB, 2019, and McCauley at al., 2021). As I have stressed above, a higher degree of complexity in the regulatory framework is justified if it enhances the intermediaries' capability to withstand unexpected losses, and at the same time improves the objective function of regulators, thus improving financial stability overall.

A substantial amount of applied economic research has compared the performance of simple vs complex rules on issues of strategic importance for regulators and banks (e.g., bank weakness, crisis forecasting) in a variety of samples and periods, in normal as well as in crisis times, collecting evidence that in banking regulation "less" may become "more".[63]

These strands of research have shown that less complex rules could sometimes do a better job in dealing with Knightian uncertainty and in meeting supervisory objectives. Moreover, theoretical and empirical studies have documented that the complexity of rules impact the ability of regulators to oversee them, while simpler rules may increase the incentives for their enforcement from the perspective of both regulators and financial institutions (Becker and Stigler, 1974; Glaeser and Shleifer, 2001). Simpler rules can also perform better with respect to changes in the incentives of regulated entities. When banks modify their structure and business models over time, internal models based upon the use of past data may become a not viable option to calculate current risks, even if we leave aside their inherent complexity (Rajan et al., 2015).

[63] There is an enormous amount of literature that has compared the predictive power and the relative performance of simple versus complex measures of banking activity and regulatory constraints. For example, in order to estimate the predictive power of bank weakness, simple-non-risk sensitive measures (leverage) of bank capital have been compared to their risk-weighted alternatives. Many studies indicate that less complex indicators tend to perform better or at least not worse, and this holds for a variety of samples and periods; see Estrella et al. (2000); IMF (2009); and Demirguc-Kunt et al. (2010). The same conclusions apply if the target becomes the prediction of bank failure. In this case, simple indicators (e.g., simple leverage ratios with assets equally-weighted, measures of wholesale funding, and loan-to-deposit ratio vs the Basel definition of capital ratios with risk-weighted assets, and the Basel liquidity measurements) seem to perform better than more complex ones in signalling subsequent failures in a cross-country sample of large banks during the GFC (Aikman et al., 2014). In the case of a modelling approach to estimate risk in financial markets, simple models have been found to out-perform more complex ones, as the number of assets in portfolio increases; this appears as a consequence of the uncertainty associated with over-fitting the complex model relative to the simple one (Haldane, 2012).

There is an increasing number of reports and studies, not only from the financial industry (which is to be expected), but also from academics, and even from the international community of regulators, which draws attention to the challenges/difficulties for banks (and other financial institutions) to develop and keep functioning the systems and control procedures needed to implement the whole range of reforms finalized after the GFC.[64]

In this context, Haldane (2012) suggested that 'catching a frisbee' is in some ways like 'catching a crisis'. One of the reasons why dogs tend to be successful with frisbees is that, rather than sitting down and trying to solve complex optimization problems, they stick to simple rules that are not 'optimal' in any sense but work well most of the times. More generally, in an uncertain environment simple rules-of-thumb can work better than complex decision-making systems (Signorini, 2017).

In principle, the evidence collected so far, seems to call for greater simplicity in regulation. However, even if simple rules can be attractive, they cannot be considered a panacea or a supervisory goal per se. It is to be recognized that modern finance has produced a complex system subject to uncertainty, whose complexity cannot be reduced to zero simply by a government intervention.

I wish to underline that addressing systemic risk in a complex financial system should not entail the replacement of overly complex rules with overly simple or less stringent regulations. There are many instances - even in the reforms finalized after the GFC - where simple rules (or simple metrics) may have not helped in reducing the degree of regulatory complexity (e.g., the various proposals on bank structural reform, or the calculating methods envisaged for a 'simple metrics', as the leverage ratio, the public interest test to enter resolution, and minimum requirements of eligible liabilities). It can also be the case that apparently simple definitions have been likely to evolve into regulations that are too complex to design, implement, and enforce (e.g., market making, proprietary trading, and living wills).

In designing a balanced approach to regulation, a feasible way out would be to reduce the complexity in financial rules that is assessed to be unnecessary, in order to minimize both the costs of crises and the costs of preventing them. The real (and difficult) challenge would be to define criteria and methods to assess the degree of unnecessary complexity in regulation. To this end, this paper proposes some options affecting the content of the rules, the regulatory policy mix for certain financial sectors, as well as the rulemaking process.

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[64] These concerns have been expressed by the (the) Chairman of the BCBS, S. Ingves. Speaking at a conference in Santiago de Chile, when the second round of the Basel III framework was finalized, he reported - as an indicator of the difficulties being encountered by banks – that the most downloaded document from the BCBS web-site was on the criteria and procedures for data aggregation and risk reporting systems. For extensive references to these reports and studies, see Ingves, (2016).

7.2 Some possible options

Proportionality

Prudential regulation may become too complex when the same requirements are applied equally to all entities. This problem emerges for example when the costs of implementing the prudential framework are higher than the associated public policy benefits for smaller banks than for larger ones. Specific studies, especially for the US banking market, outline that the cost of regulation is borne to a larger extent by smaller banks, given the existence of economies of scale in regulatory implementation (Dolar and Dale, 2020; Feldman et al., 2013; and Bank of England, 2021).

The costs of a too complex framework could be mitigated by designing simpler rules, in order to allow regulators to set regulations whose costs are effectively tailored to the riskiness of the affected entity. Implementing proportionality in regulation would imply that smaller and less sophisticated institutions should benefit from exemptions or simplified approaches to some rules. Criteria should be designed to identify those banks for which prudential regulation could be simplified without reducing their resilience to external shocks. In doing so, regulators would more precisely limit the costs of regulations in relation to their benefits.

However, from the regulators' perspective, a careful balance should be struck in the concrete design of a new prudential framework for smaller banks. Proportionality should be linked to the riskiness of banks' assets and should not produce a reduction in the overall liquidity and capital requirements. Regulators should not overlook the possible accumulation of risks in many smaller institutions that could trigger systemic concerns (too-many-to-fail). These banks should not be supervised through less intensive approaches.

In this case, reputation risks for regulators can increase unexpectedly. It could be the case that smaller banks are not less likely to enter a situation of distress: if they have similar business models, they may well get into trouble simultaneously. Moreover, small banks sometimes belong to networks of interconnected institutions, which may be conducive to a systemic impact in the case of a crisis (Enria, 2019). To this end, regulators (or even independent bodies) should perform on a regular basis an assessment of the effectiveness of regulations, their interactions, and potential regulatory failures, which should serve as a tool to effectively define tailored regulatory actions. Moreover, regulators should avoid that proportionality implementation could give rise to impediments to banks' dimensional growth and asset diversification.

Regulators are increasingly paying attention to the issue of proportionality, at the global level (i.e., BCBS) and within some key jurisdictions (i.e., in the EU, and in the UK). The common objective is to reduce the regulatory complexity that is considered unnecessary. In this respect, stable, simple and fully implemented rules can be effective.

The Basel framework provides minimum standards for prudential regulation that have been in principle designed for a precise sample of banks, i.e., those that are larger, complex, and internationally active. [65] Among the BCBS participating jurisdictions, there is a variety of implementation approaches. In some cases, the Basel requirements apply to largest banks, while in others core regulatory requirements are broadly the same for all banks, irrespective of their size or activities, and some waivers and/or simpler rules are provided for certain small and non-complex banks.

The majority of the jurisdictions participating to the 2021 BCBS survey on proportionality practices have indicated that they have proportionality measures in place (BCBS, 2021). Proportionality is acknowledged as promoting banking stability, reducing unnecessary regulatory burden and compliance costs, and making effective use of scarce supervisory resources. However, challenges remain, due to the diversity in the design of proportionate approaches (i.e., how to define the tiers, which metrics to use, and how to maintain a level playing field and avoid regulatory arbitrage) and to how proportionality is implemented in practice (i.e., what are the requirements to be eligible for simplification and adjustment, how to ensure comparability across banks, and how to achieve a net reduction in compliance costs and stress on supervisory resources and constraints). [66]

In the EU, the BCBS standards have traditionally been applied to all banks, in order to ensure a level-playing-field across the EU Member States, and to ground risk exposure calculations on the same criteria across banks. However, this policy stance has not denied the proportionality principle, since the bulk of the EU regulatory complexity mainly refers to the banks adopting internal models and having a systemic footprint.[67] More proportionality in the EU rules has been introduced in the

[65] While the Basel framework has, in principle, a limited scope of application, the concept of proportionality is embedded in other parts of the work of the BCBS. In particular, the BCBS Core Principles for Effective Banking Supervision, which, unlike the Basel framework, are universally applicable, say that supervisory practices should be commensurate with the risk profile and systemic importance of the banks being supervised. See BCBS (2012).

[66] In the US, a series of policy and regulatory initiatives has been undertaken under the Trump Presidency with the objective to produce a structural change in supervisory and regulatory approaches. The key word of that regime change was 'tailoring', that is, setting prudential standards in line with the size and risk profile of the supervised institutions. The overarching principle was to ease the 'unnecessary' regulatory burden to support the contribution of bank lending activities to the real economy. However, a more in-depth analysis of such initiatives has shown that they risk reversing the main elements of the Dodd-Frank Act (DFA), the key piece of legislation introduced in the US in 2010 in response to the GFC. For more detailed analysis, see Trapanese (2020).

[67] Recently, UK regulators have indicated possible options to reshape prudential requirements in the sense of a simplification for smaller banks. In particular, they have envisaged two approaches: a 'fully streamlined' approach, which would take the existing prudential framework as a starting point and modify those elements that appear over-complex for smaller firms; and a 'fully focused' approach to capital requirements, based upon

last regulatory package, entered into force recently (the so called CRD5-CRR2 package).[68] The incoming implementation of the last part of the Basel III framework could help further streamlining the regulatory framework in the specific areas that need such an adjustment (Angelini, 2021).

Entity- vs activity-based approaches.

The GFC has demonstrated that systemic risk is not confined to the traditional banking system, and that non-bank financial institutions (i.e., investment banks, insurance companies, investment funds) may generate systemic instability. Within the post-GFC regulatory repair, two options have emerged for dealing with non-bank systemic risk. The first option has been aimed at regulating financial entities through prudential requirements tailored on the specificities embedded in their business model;[69] the second seeks to address the externalities stemming from the activities potentially creating systemic threats, irrespective of the types of entities engaging in them.[70]

Given the recent evolution of the international financial system, entity- and activity-based regulations should be seen as complementary, especially in some areas requiring a consistent treatment of risks across the financial system. Since an entity-based regulation is well suited (through capital, liquidity, and risk management requirements) to address the risks stemming from the failure

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a much narrower but more conservatively calibrated set of prudential requirements. See Bank of England (2021).

[68] This has been thorough the definition of the Small and Non-Complex Institution (SNCI), which entails simplications in a number of key supervisory fields (reporting systems, market disclosure, liquidity requirements, interest rate risk in the banking book). SNCI is identified based upon a series of quantitative and qualitative criteria (for example, its total assets cannot be above 5 billion euro). More generally, CRD5-CRR2 includes simplified methods for market and counterparty risks, and more proportionality in the fields of governance, internal control systems, remunerations, and supervisory evaluation process. Further progress on proportionality is expected based upon the delegated technical standards and guidelines to be issued by the European Banking Authority (EBA) for reporting and supervisory process. See Angelini (2021).

69 Within this option, the legal entity's charter guides its applicable regulatory regime, for example, commercial banks are subject to one set of tools, insures to a second set, investment banks to a third.

[70] These two approaches can be studied with reference to the US response to the GFC. The first relies on the designation – by the Financial Stability Oversight Council (FSOC), created by the DFA – of systemically important financial institutions (SIFIs), entailing a system of more stringent prudential requirements (such a designation requires a structured procedure, involving the interaction of different official agencies). SIFIs enhanced supervision (mainly by the Federal Reserve) is conducted through tools based upon traditional entity-based regulation (albeit with some adjustment, since they apply to different legal entities). The second approach enables the FSOC to target – through non-binding tools (recommendations) - systemically risk financial activities, irrespective of which firms engage in such activities. Examples are the creation the Consumer Financial Protection Bureau (CFPB), focused on activities of consumer credit and payment systems, and the DFA reforms on derivatives, which target the trading activities irrespective of who engages in them. See Mason et al. (2018).

of a systemically relevant financial institution, both approaches should be seen as essential components of an integrated strategy to effectively regulate new and emerging forms of systemic risk.

This would contribute to avoid regulatory arbitrage and the transfer of risks outside the regulatory perimeter, while reducing complexity (ERSB, 2019). This holds not only with respect to non-bank financial institutions, but also with respect to non-bank fintech firms, which are becoming very active in offering services in a number of areas (payments, wealth management, sale of insurance products, loan underwriting) previously offered by banks (Restoy, 2021).

Over the last few years, a tendency has emerged in the regulatory community to consider these two approaches as substitutes, with a view to replace entity-based regulation in favour of activity-based regulation, since it is believed that the latter has the potential to address more effectively some of the risks stemming from market-based finance, and limit the forms of regulatory arbitrage that accompany entity-based regimes.[71] However, this tendency to de-emphasize (or even eliminate) the entity-based regulation in certain segments of the intermediation may amplify complexity in financial regulation, and in the overall financial architecture. Even a well-designed activity-based regime cannot on its own prevent individual non-bank firms from transmitting systemic risk, because an individual firm's systemic riskiness is inherently a product of the interrelations among its various activities and risk management practices.[72]

In theory, an effective activity-based regime would require a single financial stability regulator with binding powers and tools, and apply to all firms that engage in a particular activity, regardless of the entity's legal charter. This is why it is much harder to implement effectively, particularly in jurisdictions with a multiplicity of institutional layers (e.g., in the US and the EU), where this fragmentation often leads to coverage gaps and undermines regulators' ability to address risks.

A smoother rule-making process

[71] Continuing with the US case, in 2017 the FSOC was required to focus primarily on its activities-based rather than its entity based authority, and a number of constraints and procedural barriers was envisaged to its SIFI designation process (with the result to reduce the likelihood of such a designation). For some authors, this tendency has emerged also in other jurisdictions and also within international coordinating bodies (e.g., within the FSB). See Kress et al. (2019).

[72] Individual activities may pose limited systemic risk if taken in isolation, while much greater systemic risks can be created when different activities are combined together in a single firm. The large failures of individual firms during the GFC (AIG, Bearn Sterns, and Lehman Brothers) were all ultimately driven by a combination of many different activities, combined with lax risk-control procedures and aggressive investment strategies.

A lower level of complexity could be achieved also by modifying the 'rules' governing the rule-making process in finance. Especially after the GFC, some jurisdictions (e.g., the EU and the US) have adopted a two-tier model in rulemaking, where the primary legislative acts are complemented by secondary technical standards issued by regulators. The diversity in substance between these two layers has progressively disappeared: both are composed of hundreds (if not thousands) of pages, articles, paragraphs, chapters, and titles, with a plenty of technical details in each constituent part.

Limiting the analysis to the EU, the EU legislative process includes several layers at the EU (Commission, Council, Parliament, Regulatory Authorities) and the national level (Government, Parliament, Regulators), and a high number of interactions with other stakeholders and interested parties.

After the GFC, this multi-layer process has produced a single rulebook on financial regulation, consisting – up to now - of more than 80 acts pertaining to the first (legislative) tier (directives, regulations, and delegated acts), accompanied by a massive waterfall of 200-plus technical standards, 200-plus guidelines and many other types of documents (carrying different enforceable powers), issued by the EU sectoral regulatory authorities (Berg, 2022).[73] The overall count should be completed by the national implementing acts issued where needed (e.g., in the case of EU regulators' guidelines), whose precise number is impossible to calculate. These pieces of legislation/regulation cover a long list of issues (such as prudential requirements, crisis management, deposit guarantees, short-selling, market abuse, investment funds, alternative investments, venture capital, OTC derivatives, markets in financial instruments, insurance, auditing, accountancy, and credit ratings). A similar pattern has been followed in other jurisdictions (e.g., in the US).[74]

This rulemaking process has added rigidity and complexity to the system: given their technical content, these acts need to be changed together to address new risks. This has created a rulebook difficult to manage and to understand (even in terms of its linguistic comprehensibility).[75]

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[73] This calculation does not take into account the guidelines and other documents issued since 2014 by the ECB- Single Supervisory Mechanism. As to the length, some early estimates indicate more than 60.000, as the likely number of pages of the final post GFC rulebook in the EU (Haldane and Madouros, 2012).

[74] For a detailed evidence on the results of the post-GFC regulatory process in the US, see footnote 37 above.

[75] Amadxarif et al. (2019) have used language processing and network analysis techniques to measure textual and linguistic complexity in the post-GFC regulatory texts (mainly from FSB, BCBS, EU, and UK regulators). Dimensions of processing difficulty for a provision include its length, lexical diversity, use of conditional statements, and the overall readability of its sentences (this is the 'local complexity'). When processing difficulties can be resolved only after accessing information outside the immediate context of the provision, (cross-references or regulatory precedents) they refer to a 'global complexity' dimension. Their findings point towards the existence and growing importance of both dimensions in the post-GFC reforms. In particular, the rise of highly complex provisions is most visible for global measures based on cross-references, since the

Less complexity would require a different design of the rulemaking process. For example, the first layer of primary legislation could be built essentially through principles of general application, whose validity is supposed to last for longer. The concrete implementation of these principles should be left to regulators' mandatory technical standards. These standards could be modified more smoothly by regulators once new developments emerge (with no need to undergo the primary legislative process and its associated time lags), as it has been done in some cases during the COVID-19 emergency situation.

Such a model would allow more flexibility in financial regulation, in order to ensure a smoot response to future unknowns. In some jurisdictions (e.g., in the EU), this new rulemaking model would also help in streamlining the institutional financial architecture.

8. Conclusions

In a financial system dominated by uncertainty (rather than measurable risk), excessively complex financial regulation may not only be unsuitable to control systemic risk but even add on it. Previous paragraphs have indicated several channels through which excessive regulatory complexity can impact financial stability, since it generates for regulators the illusion of a perfectly-supervised system, undermining their ability to control risks. At the same time, regulated entities are confronted with a rulebook too complex to understand or to comply with.

I have outlined an argument that addressing systemic risk in a complex financial system should not entail the replacement of overly complex rules with overly simple ones or less stringent regulations. I have indicated that a reasonable solution would be to reduce the complexity that is assessed unnecessary. This is no doubt a difficult task. To this end, some policy options could be considered. In certain cases, regulators are already pursuing viable way-outs, albeit through differentiated modalities across jurisdictions.

First, a greater degree of proportionality in rule-making would allow regulators to set rules that are more effectively commensurate to the riskiness of the affected entity. However, regulators should not overlook the possible accumulation of risks in many smaller institutions that could trigger systemic concerns. Second, in some areas (e.g., non-bank financial intermediation, and fintech)

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comprehension of the provisions requires accessing and organizing information that is articulated over long chains of interconnected terms and texts. Highly complex provisions appear also in the distributions for local measures for binding rules, since provisions have become longer, with higher lexical diversity, and conditionality. They indicate that the post-GFC reforms have generated a set of rules that require retrieving a lot of material, containing several concepts and exceptions, whose availability for the reader is neither immediate nor easy to understand (or even to get).

activity-based regulation could complement (rather than replace) the existing entity-based regulation, in order to avoid regulatory arbitrage and the transfer of risks outside the regulatory perimeter. Third, less complexity would require a different design of the rulemaking process, allowing greater flexibility in financial regulation, in order to ensure a smooth response to future unknowns.

Complexity versus simplicity in financial regulation may well represent a test bench for regulating authorities. In particular, regulators may wish not to be characterized as behaving like the Isaiah Berlin' hedgehog, "who knows one big thing", and relates everything to a single central vision, one system (fixed for ever), in terms of which he understands, and decides everything. Rather, regulators may prefer to be similar to the fox, "who knows many things", and pursues many ends, often unrelated and even mutually contradictory, connected only in some de facto way, and seems to be more able to deal with new developments. Behaving as the Berlin's fox, regulators would adopt the degree of flexibility that is needed to deal with a fast-changing external environment.

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