Artificial senses: Measuring finance and the economy at the relevant speed and scale

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Abstract. The paper offers a high-level exploration of how ongoing change affects the validity of some of the fundamental choices that shape our "inner world" and its relation to the world outside it. It tries to suggest a vision of the economy and finance that could support measurement and analysis at the speed and scale required for staying in control of the system. It tries to deduct from that vision some conceptual adjustments that could lead to practical solutions applicable in today's environment.

Authorities' approaches to regulation seem to frequently build on the assumption that markets can be nudged towards self-organising behaviours. It appears that the speed, scale and depth of the digital explosion have created disruption too fast and profound for self-organisation forces to respond to the usual ways of nudging. We need to imagine and adopt some new ways of nudging. The proposed approach builds on the hope that relatively limited but decisively implemented infrastructural measures could unleash sufficient transformational power to help the system to self-organise in a way that would remain sustainable in the dawning digital era.

This paper represents the views of its author, not necessarily those of the ECB.

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1. Introduction

Some fundamental and accelerating change is afoot in our world. Striking progress in technology, especially in information technology, seems to play a driving role for change in many other fields of human activity.

Increasingly we understand that some of the things we took for granted and that we experienced as permanent and constant in mankind's memory are actually transient and are changing, too. Some such as plate tectonics will remain too slow to perceive, but we now can measure them whereas others such as climate accelerate, so we now can perceive change more directly, with our own senses.

If it was not easy to see earlier, the crisis has revealed to all, beyond doubt, that some of our established ways of measuring and analysing the economy and finance don't work as well as they used to and that they failed us at critical moments. A gap has grown between the fast developing economy (and finance) and our capacity to measure, understand and stay in control.

In the area of measurement, many significant actions have been taken since to address that gap, for instance the G20 has launched a global Data Gaps Initiative. Many of those actions describe information products destined to plug gaps that appeared during the crisis. Some of them establish entirely new products, such as large-scale collections, for instance of individual transaction reports as for OTC derivatives, whereas others aim at gradual improvements of existing statistics. Some of the measures are supported by legal acts, usually at single constituency level, leading to patchwork implementation at global level, others by broad standards subject to free interpretation and voluntary application. Nearly all measures and relevant legislation focus almost exclusively on the desired output whereas much of technical design and execution, for instance on the input side of data collection processes, are left for a good part to self-organisation in the markets – see the Trade Repository approach to OTC.

Experience with the collection of data on OTC derivative transactions launched by CFTC in the USA and by ESMA in the EU has shown that markets and their practices, as they stand, cannot deliver near-time, large-scale micro-data that would fulfil the needs for information and speed that businesses and authorities alike faced in the last crisis. Efforts to bring together, in a single database, high-volume flows of granular data collected from many sources in a complex, competitive industry spread across several constituencies have revealed that more attention must be given to design. Collecting such data flows through a network of independently operating Trade Repositories driven by their own business interest and constrained by their practices and systems tended to add to the problem by generating reports in multiple formats and languages. Self-organisation of measurement processes among the financial industry and its regulators didn't work the way it was hoped for by the regulatory community. The data didn't come as expected[1].

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1 http://www.cftc.gov/PressRoom/SpeechesTestimony/opaomalia-34 Keynote Address by CFTC Commissioner Scott D. O'Malia, The Future of Financial

Whereas self-organisation should not be fundamentally questioned, the question remains about why it didn't work in this case. That question seems important, as our answers could lead to designing a frame in which self-organisation works, in which governance can effectively and safely steer the free activity of market agents and their regulators towards a technically competent result. We might need to identify and establish enablers that have become necessary and are missing.

A good starting point could be to give a closer look to the substance we try to measure, analyse and control. At the heart of that effort could be in-depth consideration of the fundamental changes brought about by the ongoing digital explosion, as they affect at the "atomic" level the substrate on which the economy and finance operate. Those changes are widely understood to also affect the behaviour of those systems at macro-level, be it only through the speed and global connectivity they enabled even at the level of individual agents.

The challenges we face from technology-driven change are exogenous to the economics and statistics community. Recognising them is not straightforward as they are diffuse and ubiquitous, not easy to point out specifically. Moreover, their impact is not easy to understand in the traditional conceptual frameworks that shape our perception and our thinking. Technology-driven change is profoundly disruptive as de facto it happens at micro-level, mostly below our awareness threshold. It is difficult to identify because it affects ancillary technical aspects of nearly each element of the economic and financial system; each one of those changes can be seen as irrelevant to the overall system, yet all those micro-changes compound and the resultant macroscopic evolutions emerge gradually. Similar to other too-slow-to-see developments such as plate tectonics, those changes are hard to recognise, as the visible macroscopic system, observed from our legacy perspective seems stable. And still, technology-driven change unfolds much faster than the communities affected are collectively adapting to it, hence the gap between the system we observe and our capacity to measure, analyse and understand it should be expected to keep growing.

If our way to look at our environment prevents us from seeing something important, it might be useful to look at it in another way, from another perspective. In the words of Sir William Henry Bragg, Nobel Prize for Physics, 1915: "*The important thing in science is not so much to obtain new facts as to discover new ways of thinking about them.*" We might need to develop a different perspective on or vision of the world we live in and of the system in it that we study.

To ease the genesis of a different perspective in the reader's mind the text is written avoiding as much as possible the use of current technical language of economics and statistics, as that language carries all the habitual meanings and associations, and would thus risk to anchor us in the habitual perspective, preventing a fresh eye.

The paper offers a high-level exploration of how ongoing change affects the validity of some of the fundamental choices that shape our "inner world" and its relation to the world outside it. It tries to suggest a vision of the economy and finance that could support

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Standards – SWIFT Institute, SWIFT's Standards Forum, and the London School of Economics and Political Science, London, England measurement and analysis at the speed and scale required for staying in control of the system. It tries to deduct from that vision some conceptual adjustments that could lead to practical solutions applicable in today's environment.

Authorities' approaches to regulation seem to frequently build on the assumption that markets can be nudged towards self-organising behaviours. It appears that the speed, scale and depth of the digital explosion have created disruption too fast and profound for self-organisation forces to respond to the usual ways of nudging, especially when the populations involved are very large and global, spanning all cultural, national and legal systems in the world. We need to imagine and adopt some new ways of nudging. The proposed approach builds on the hope that relatively limited but decisively implemented infrastructural measures could unleash sufficient transformational power to help the system to self-organise in a way that would remain sustainable in the dawning digital era.

The paper carves out its conclusions on what feasible steps to focus on by taking a naïve approach from outside of finance and the economy, by trying to cast a fresh eye free from the economic concepts we try to measure. That approach is taken consciously in the awareness that an approach from inside finance and economics would likely frame the author and the reader in the conceptual world and the language of these disciplines. A useful analogy for this approach can be found in the life sciences: genetics and molecular biology speak a language very different from the language of zoology. Whereas these two disciplines allowed us to reach a much deeper and richer understanding of the animal world, they wouldn't have progressed by breaking down the language of zoology to ever more microscopic levels. Molecular biology and genetics developed from chemistry. In the same sense, the author believes that the digital revolution forces us to approach the study of finance and the economy from a consideration of reality that is free from the language and the conceptual frame of these two disciplines. If successful, that excursion should give us much more powerful tools at the interface between reality and the disciplines of financial analysis and economics that should allow us to develop these two disciplines to new heights.

2. General considerations on context and perspective

The considerations that follow aim to highlight the context and the perspective that guide the conception of the ideas subsequently presented.

The substance we study – abstract things, representations, signs

Whereas a main product of the economy and finance is the world of physical products we live in and the physical processes that deliver them, much of the action does actually happen in an abstract world of agreements, promises and expectations, perceptions, concepts and language, and emotions, the latter being far out of scope here. All of those immaterial things happen inside human brains and in the interaction among them and between them and the "real world", which also includes computers.

Abstract objects are handled using signs, representations accessible to our senses. Whereas language is a system of signs, any physical object can be used as a sign as well; non-linguistic sign systems can be built. Documents and data are representations used for intermediation in and about the immaterial world of finance and the economy. Whereas traditionally representations were used for intermediation, direct or indirect, among people, a new species has entered the game and has changed it: networked computers who now handle volumes of representations (data) far greater than what humans could, potentially at speeds that humans cannot follow. Moreover, computers create representations by processing other representations. Those representations feed into action or are presented to humans. Questions arise about the control humans have over actions taken by computers and about the reliability of meaning humans extract from the representations presented to them by computers. Where meaning can be verified through conversation with a human, it is more difficult to do so with computer systems.

A look at the nature of the substance we study and want to measure should hence include a brief consideration of the brain and how it interacts with its environment.

Our brain and the world outside

The human brain is a central element of the economic and financial system. This paper adopts and builds on the view that each human brain generates a constantly evolving model of the "real world", an "inner world" that is that brain's individual representation of the "outer world", entirely based on continuous processing of its individual stream of sensory perceptions that result from interaction with the "outer world", accumulated throughout the person's lifetime. It goes without saying that those sensory perceptions include what comes from other humans, which is likely to exert a strong influence; culture is just one expression of that influence of others on an individual; documents and data are a channel for such influence.

The "inner world" model formed by a brain is validated on an ongoing basis through permanent predictions based on current perceptions and on stored memories, matched with ongoing experience. The brain can also generate different "inner models" of a same perception, as is well illustrated by many well-known, so-called optical illusions. Hence a single observer can potentially choose between several models, or interpretations of the same reality. Those different models can represent a person's different, alternative world views, which can coexist and enrich their perspective on the world, opening more possibilities.

It might also be useful to consider populations of brains and phenomena such as clusters, waves, resonance, etc. that can occur across a population of interacting brains.

Measurement and analysis can create representations that, shared among a group or a wider population, can take a group closer to certainty and enable decisive action. They can help put a group into a state of "being in control" in an uncertain environment.

Language and data

The word “data” begs a definition that supports the reflection conducted in this paper. It is generally accepted that a reader of “data” needs “metadata” for the data to make sense. Data makes sense to a human reader when it can be translated into a statement in a comprehensible language. One could see a necessary condition of data quality in that it can be translated unequivocally into a statement in natural language. Indeed, if data can be translated into two or more different statements in natural language, the information it carries loses its certainty; such data cannot be trusted. It follows that good data must be equivalent to natural language; In that sense, data is condensed natural language.

A simple example: the statement “Peter is 48 years of age and 1,80m tall” can be condensed into the data set [Peter; 48; 1,80] and remains good data as long as it travels with the formula {[X; Y; Z]; “X is Y years of age and Zm tall”}. Many data sets [X; Y; Z] can be stored together with a single copy of the statement “X is Y years of age and Zm tall”; together they are good data. Combining the data set [Jane; 15; 1,60] with the statement template gives the statement “Jane is 15 years of age and 1,60m tall”.

One could quip that data is to language what powdered milk is to milk. Powdered milk is much lighter than milk and much cheaper to store and transport. If one knows what to add to powdered milk, it can come back to milk or very near it.

If various types of powdered milk from diverse sources are mixed and information about the origins and powdering processes is lost, the “reconstituted” product might not be too close to milk. Quality might suffer. That far, powdered milk can offer a nice analogy to our experience with data.

Trust in data? (1) The chain from reality and perception to language and data

Our senses deliver perceptions of our physical environment to the brain in the form of the signals they generate quite “mechanically”. In those perceptions, our brain identifies objects that correspond to concepts for which representations are stored already. Where no concept exists yet, the brain might create a new concept, perhaps built from or close to existing ones, and thus create a new identity that is then attributed to a perception – a new object is created. Alternatively, the brain might not identify an object. Some people don’t “see” vertical lines because following an accident their brain doesn’t hold the tools to identify them; Einstein also famously said “*it is the theory that decides what we can observe*”. This can also be taken to mean that, much rather than seeing an absolute reality, we project concepts we know onto the perceptions our senses produce from their interaction with our environment; that also aligns well with the experience that different people can see the same physical environment quite differently. In other terms, an object exists only in the mind of the observer. Whereas different people can agree more easily on the existence of a physical object that is its own sign that directly imprints our senses, the same is more difficult when the object is immaterial, abstract.

Where a concept and a representation of an object exist, they might be associated with a name and language or other signs. Names, language and signs can be stored physically in the shape of a document in any of the known media.

Whether different persons perceiving a same reality, for instance a physical object or a document, generate the "same" concepts and mental representations cannot be known. The use of same names, language and signs only gives an indication. Philosopher Ludwig Wittgenstein created the concept of "language game", whereby people, objects and their actions are combined in a game that involves conversation and action. Observation of that game can give a stronger indication of the compatibility of perception and representation among different people.

A simple example of language game involves a bricklayer, his assistant and a brick. The bricklayer says "brick"; the assistant hands him a brick.

In an abstract, immaterial environment, documents and signs are the only physical artefacts visible to the observer, excluding brain scans. It is more difficult to establish whether the same language coming from two persons refers to a "same" immaterial object, or whether the same immaterial object will inspire in two persons different signs, language, documents. Conversation between two such persons might enable some degree of verification.

Once language is documented and the document is separated from the person it becomes much more difficult to obtain certainty through communication, through a language game.

When language is condensed into data and data is separated from that language, the difficulty is compounded.

When data from many sources, separated from the underlying language, is collected in a single database, the difficulty to obtain certainty is compounded further.

When data travels through networks of computers and databases, is processed into further data, the difficulty is compounded again.

When data volumes become so high, the flows become so fast, processing so complex and the paths through the network so long and hard-to-know that human brains, however well organised, cannot follow anymore, we have something like the situation we face today.

Is there a way to establish a level of responsible trust sufficient to base analysis and action on the data?

Trust in data? (2) Facts and trusted data in an abstract environment

In physics and engineering, data usually enjoys high levels of trust and social acceptance. That strength can be linked to the scientific method that guarantees observability, testability, reproducibility. It is also supported by the use of rigorous, disciplined technical language, shared, accepted and respected across society even if not every member is a professional physicist or engineer. As a result, the "real world" and the "data world" map well and real world behaviour is faithfully reflected in the data representing it. Such data can be computed and the results deliver testable predictions.

That strength also builds on more than a century of spectacular success in engineering, experienced by everyone in their daily life.

The strength of data, including physical and engineering data has a social aspect. Physical and engineering data is accepted as equivalent to something real; we don't need to confirm the data through our own perceptions to trust it, for instance data about radiations we don't see. Also, we trust that others perceive the same physical reality as we do. That creates strong social consensus around the reality that we accepted as being described by physical and engineering data. Social consensus about perception allows social consensus about the identity of physical things and the language about them. Social consensus gives some physical things a social reality; everyone will identify a tennis ball among many other objects if asked to do so.

An important question about trust in financial data is to know whether and how a similarly strong social consensus about identity and language on abstract things could be achieved without our senses perceiving them directly. The beginning of an answer could be found in law. Law can be seen as a powerful tool for building social consensus. Law can confer to abstract things similar social reality as that enjoyed by physical things. Broad social recognition can also make abstract objects into "facts", another ill-defined term that however expresses the property of something enjoying socially shared acceptance beyond discussion.

Luckily, some abstract objects central to the economy have their existence and representation recognised through law: humans, legal persons, contracts.

Practical action, theory, vision and utopia

Most organisations function on a modus operandi of concrete, practical action delivering tangible results in a short time frame, embedded in annual work programmes and budgets, conducted within a stable conceptual and regulatory frame. Successful delivery of results ensures sustained stability of the conceptual frame within which it is conducted. Such stability can be challenged when that conceptual frame doesn't match the environment anymore and the organisation begins to deliver less successfully. It is quite possible that most people involved in action in a larger group are not even aware of operating within a conceptual frame that results from choices made by other people; the frame can be taken as a given, as quasi-natural – it is likely to be taken as such by a majority. It can happen that all living members of a society are not aware of the existence of such a conceptual frame, having forgotten that choices were made in earlier generations and why they were made. Possibilities that do not conform to the established frame are likely not considered or accepted.

Therefore, when change occurs in the environment and established, normal practice begins to show failures, the conceptual frame is not questioned at first. When failures accumulate and the conceptual frame begins losing its validity in a changing environment, pressure for questioning and adjusting it mounts, usually driven by a few individuals at first. In his book "Structure of Scientific Revolutions" from 1962, Thomas Kuhn describes the mechanisms by which new scientific theories emerge when an established one reaches its limits and doesn't deliver satisfactory answers anymore. A good illustration is found in the turbulent emergence of Albert Einstein's relativity theory and of Max Planck's quantum mechanics at a time when established science increasingly failed to explain observation or to predict outcomes of experiments.

Vision could be said to be orthogonal to theory. Theory is understood here as a body of knowledge about (a part of) the world and the conceptual tools to apply that knowledge in practice. Theory also shapes the way we look at the world and what we see. Albert Einstein said "*it is the theory that decides what we can observe*". Vision is understood as the choice of a perspective adopted to view the "outer" world or part of it; the term world view could apply as well. Similar to eyesight, vision is very concretely concerned with perception in the present; in this work it has little to do with the generally associated meaning of vision as an unreal, futuristic, imaginary creation of fancy.

A simple illustration is found in two alternative visions of the solar system (figure 1).

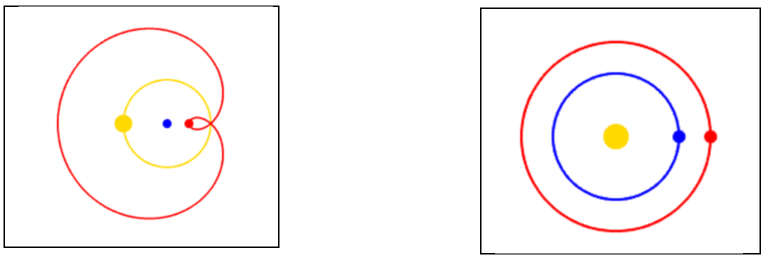

Fig. 1. the medieval Ptolemaic, geocentric vision (left) and the modern Copernican, heliocentric vision (right)[2].

Under both visions of the solar system, the same Newtonian theory of gravity applies, and it should give the same results in terms of prediction of planetary positions at any time. However, whereas calculating the orbit of Mars in the Copernican vision of the solar system is an easy task, doing the same in the Ptolemaic vision involves much more complicated mathematics as the red orbit on the left in Fig. 1 suggests. In more technical terms, choosing a vision of a system could be compared to choosing a conceptual referential, a model of the world, in which to look at and describe the system. As to the question of which vision, which model is true, we can transpose as an answer the insight offered by George E.P. Box, statistician: "*All models are wrong; some models are useful*". From there it seems beneficial to engage into the search for a vision that makes

[2] Source of the illustrations: http://images.google.de/imgres?imgurl=https%3A%2F%2Fupload.wikimedia.org%2Fwikipedia%2Fcommons%2Fe%2Fea%2FApparent_retrograde_motion.gif&imgrefurl=https%3A%2F%2Fen.wikipedia.org%2Fwiki%2FCopernican_Revolution&h=256&w=512&tbnid=d-2Q8WwFkk4YVM%3A&docid=_D5z93ryjK14lM&ei=YJsIWLOZBqaIgAaf4KuwAg&tbm=isch&iact=rc&uact=3&dur=1353&page=0&start=0&ndsp=28&ved=0ahUKEwizydymlenPAhUmBMAKHR_wCiYQMwg8KBgwGA&bih=773&biw=1536

it easier to apply the theoretical toolkit we selected for studying the system or for designing a new theory if needed.

The key theoretical insight one can read from much of post-crisis regulation is that we need to look at the financial system as a whole, globally, and that we need to do so on the basis of granular data, at transaction level that we acquire near time. We could thus aim at choosing a vision of the financial system (or of the whole economy) that allows us to simplify the near-time acquisition of very large-scale data, to make processing cheaper, faster and more accurate, and understanding by humans easier.

In that context, it is useful to give a brief look to "utopia". Utopia can be seen as an attempt to envision and formulate a more complete description of the system we study as it would be transformed if changes suggested by theory and vision came to full implementation. The uncertainty of such an undertaking of mind increases rapidly, the more complex the system considered is. Still, conducting some utopian exploration can offer benefits. Firstly it gives the explorers an opportunity to fertilise imagination, facilitating the creative search for new ideas, free from the mind-shackling constraints of immediate "realism". It also helps to identify ideas that cannot work or that could lead to undesirable outcomes. Even if only few such ideas survive the test of feasibility, the remainder can provide sufficient value to justify the excursion. A little utopian exploration can thus be useful as a "laboratory" in which the impact of intended actions could be tested and plans could be refined. It can provide input into the assessment of the potential value of an idea, especially if the idea is about building infrastructure. It can provide a leadership tool to identify and align efforts that cannot be coordinated in a detailed operational manner, and to mobilise energies towards a common goal. Finally, it can give a sense of hope and confidence, and the perspective that immediate first steps could open the door to higher-value developments in the future. Of course, utopia must be handled with care, as it can also be a tool of manipulation.

The world we live in, the economy and finance

We humans live and interact within and with the physical world that surrounds us.

We interact among ourselves in many different ways, we form groups, societies and networks that can be mutually exclusive or can overlap, that range from a few individuals to many millions, that are locally concentrated or widely distributed, that are permanent or transient, that can be simple or complex, bonded by very different forces or relationships. Each individual can be attached to many of those structures, permanently to some, temporarily to others.

We interact with our physical environment, among others to create from it shelter, food, clothing and all the material things we need to sustain our life and to make it agreeable. We do so individually and collectively, through some of the groups and structures we belong to. We do it directly, or by inducing others to do so, or by enabling them or guiding their action.

Over time, humans have learned to use ever more resources and to produce ever more goods that make life better and they have learned to do so ever more easily. Much of that progress requires collective action, sometimes among larger structures. The problems of deciding what to produce and of sharing among individuals the goods produced has evolved alongside.

The process of using resources the world offers to us, producing goods from them and sharing them among us can happen in many ways, including through violence. Peaceful, intelligent production and agreed give-and-take to exchange products and services (labour being a service) could be defined as what we call the economy.

Finance can be seen as a social process that helps society to discover and decide what to produce, what activities to allocate capital to. It is also a process that helps to manage claims and liabilities among market participants, also across time. Money is the medium finance uses to perform these tasks.

Economic success: the roots and the crux in it

The continuous discovery and transmission of many ways to make ever better things and to do things in ever better ways, and the ability to organise individuals into groups and structures has given us economic success.

That success has let the human population grow, sometimes exponentially, for a long period of time.

Economic success and population growth have also revealed that the resources offered by our physical environment are finite and that it could deteriorate under the influence of human activity to the point of questioning the sustainability of economic success and, for some, eventually human life on Earth. Moreover, they have made sharing the goods more difficult to organise, leaving some with very little and most with much less than a minority. Such distributional issues can compromise the functioning of the groups, societies and structures that enabled economic success in the first place.

The digital age adds its own brand of a crux to economic success: the collision between fast-growing complexity and speed on the one hand and slow-changing human behaviour on the other seems to make our economies and societies prone to fast, large-scale events that we might find ourselves challenged to keep under control.

The exponential growth of networked machines and their performance has changed our relationship between humans and the machines and the place of humans in that socio-technical system, even if our cultures are slow recognising it and adjusting.

Control

Being in control of a system can, at the extreme, mean the ability to subject the development of the system entirely to the will of a single agent. Some of the worst experiences of mankind resulted from attempts to establish such total control on a society.

Thankfully, many social systems are too large, too complex and influenced by too many forces to even technically allow full control by a single agent. Thus only more limited forms of control are feasible, too, with a view to stability. Such more limited, functional forms of control include the ability to influence the development of the system, either into the direction desired or away from developments or events that are not desired. An even weaker form of control can be found in the ability to know in advance where the system could be going, even when one cannot influence its development; yet such knowledge can be useful if it gives sufficient notice to avert the worst undesirable events or to seek timely protection from those that cannot be stopped.

Fig. 2 illustrates a very general concept of control. In the control cycle in which measurement feeds analysis that guides action, which in turn impacts system behaviour, for instance by keeping it within defined bounds. Measurement, analysis and action must be executed at a speed, frequency and performance that is determined by the nature and dynamics of the system and by the level of control that is desired. Conversely, the attainable level of control is constrained by the means available for measurement, analysis and action. Each of those three functions is a necessary condition for control; the weakest among them constrains what control can be achieved. In the dawning digital age, the function that constrains control is, probably by quite a margin, measurement.

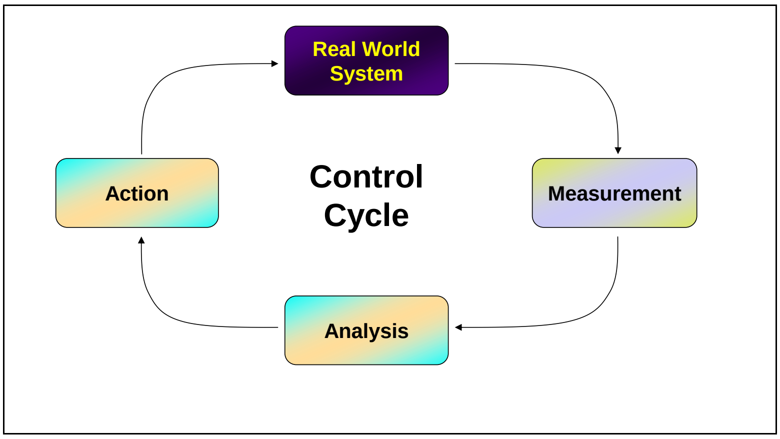

Fig. 2. The concept of control cycle

Measurement effective for control

In a simple view, measuring the length of a stick is usually understood as matching the stick against a reference object that carries a scale representing units of length. Measurement gives information about the stick, which can be combined with other information into analysis to help us decide action on the stick, for instance whether it can be loaded whole into a car or must be shortened.

Measuring a more complex, multidimensional reality, perhaps even an abstract "reality", requires at least a generalisation of that simpler concept. Measurement can be defined more generally as the production of information about the reality measured, which can be used for analysis to support action. That information, though, is likely to be more complex than a dimension, a number and a unit. It will probably require to be conveyed in the form of a more complex representation that might go beyond quantitative information.

If the system being measured is made up of many elements that interact, measurement is likely to require a representation of the system that reflects the level of complexity the analysts need to take into account for the purpose they serve. A a few numbers might not do justice to the more complex behaviours of the system measured and even less to the reality it represents. Depending on the needs to be served by that measurement, a very summary representation can be sufficient or a more detailed one might be required, reflecting in more detail the elements of the system and their interactions, and perhaps even insight into some of the elements. One could perhaps imagine media similar to the dynamic weather maps seen on TV.

Requirements for measurement that serves a control cycle are dictated by the type of control that is sought. For instance, speed and behaviour of the system, as well as the type of events expected and control intended, determine the time available for action to be completed and the frequency at which such action might be needed. Within that total time available, the performance of the functions “analysis” and “action” in the control cycle constrain the time remaining for the delivery of measurement.

If analysis requires a representation of (selected dimensions of) the complete system at the timeliness and frequency dictated by the speed of the system measured, it follows that measurement must operate at the scale and speed of that system. It could be that the representation of the system required from measurement needs to be more detailed or that aggregate representations must be built from more detailed information. The detail required can be at the level of elements of the system and their interactions. Such measurement must be fed with information granular at that same level or more granular, captured from each element and each interaction, under time constraints that allow constructing a faithful and useful representation of the system. A useful representation of the shape of a fast-moving system requires simultaneous measurement of each element, or of a sufficient sample of them, at the same time (same time-stamp). Precision of each measurement at element level must be tailored so that the system representation constructed from all those measurements is precise enough for the analysis and action needed to ensure the desired control.

Statistical methods can be used to build a system representation of acceptable quality with a sample of less-than-perfect element-level information. The use of such methods must be critically evaluated, though, as extension of their use beyond their domain of validity could affect the quality of measurement, ultimately leading to control failure.

In summary, to be effective, measurement must be at the scale and speed of the system measured and at a level of detail, precision and simultaneousness commensurate to the type of control that is desired. In other words, measurement can be seen as building artificial senses that complement and extend our natural senses where they don’t enable us to perceive a reality we need to stay in control of. Our natural senses don’t perceive the abstract world of finance.

For some aspects of modern finance, for instance management of a fast-evolving international banking crisis, the relevant scale is global and the relevant speed is real time.

Everyone needs to be in control – everyone needs adequate measurement

Every individual or group that participes in a collective activity like the economy and finance needs to be in control of their own activity and situation. Hence the considerations above apply to every market participant in the economy and in finance. Everyone needs measurement suited to their own control cycles.

Jack Welch, former CEO of General Electric famously said "control your destiny or someone else will". In a market, it would be more accurate to say that control of one's destiny is always shared between oneself and the others. However, it also seems safe to say that if every market participant's control cycle is served by better measurement, the market should be more stable, at least against certain types of disruptions. A crowd will run more safely through a forest if every individual takes away their blindfold. One might even venture to speculate that better control by each market participant over itheir own activity reduces at least some components of systemic risk.

The study of control and how to improve it in the economy and in finance could benefit from considering that systemic control is the resultant of the control every agent and group of agents in the system have about their own and others' destiny.

Control as the flip side of risk

The interest brought to control comes from the consideration that control and risk are two sides of a same coin, yet that an approach from the control side is the one more open to the application of engineering. However, the promise of engineering seems limited to the measurement part of the control cycle, and perhaps to the kind of support that analysis can enjoy from modelling and simulation. Nevertheless, that contribution shouldn't be underestimated, as it could fill one of the most apparent gaps in risk management, namely the timely acquisition and processing of information useful for analysis and action.

3. Measurement, analysis and action

The notion of system is central to this work.

System – sketch of a definition, some properties

A whole made of elements that interact. Interaction among elements determines the behaviour of the whole. Elements belonging to the system are identified; the system has a boundary, there is an inside and an outside. Elements of a system can interact with elements outside the system; outside influence is possible. A system evolves over time.

At each moment it is in a state, knowable or not, although for very large systems that can be questioned.

System is representation and vision, not reality

A system made of elements is understood here as a representation, itself built from representations of objects we perceive. The system is a (partial) representation of the real thing; it is not the real thing. The real thing is not split in systems; it is one – systems are purely a creation of the observer: systems don't exist in nature. That is important as the same reality can be represented by many different systems, depending on the observer's means, objectives and needs.

A same reality can be represented as a system in many different ways. Many systems can be imagined for representing aspects of a same reality. For instance a human body can be represented through the skeletal system, the muscular system, the nervous system, the digestive system, the cardio-vascular system, the skin and hair system, the microbiome, etc.

Systems representing different aspects of a same reality can overlap, for instance "limbs" and "skeletal system" for a human body. Sets of systems can be combined into a more complex representation, mapping reality with or without overlap.

A specific aspect of an object can be represented by diverse versions of a same system, with different degrees of detail and precision, for instance the human cardio-vascular system can be represented as just the main veins and arteries or down the the smallest vessels.

Model, built from systems

A model of a reality can be built by combining systems representing aspects of that reality, each one at a suitable and feasible degree of detail. The choice of systems will depend on the analytical purpose and the means available.

For instance, a rough analysis of human movement might be served well enough by a model made of a simple version of the skeletal system and the muscular system. Including even a very sketchy representation of the nervous system can add considerable sophistication to the analysis. The digestive system, the cardio-vascular system or the microbiome might be represented just as a notional mass that needs to be moved along, adding inertia, or they can be ignored altogether.

Model, simulation and prediction, measurement

The systems that compose a model interact to generate the model's behaviour that can then be studied, for instance by letting the model run in a simulation.

A model (single system or combination of several systems) can easily be too complex for a brain to represent or for a brain to figure out the model's behaviour and evolution over time. Computers can be used to represent very large systems and models and to calculate their states over time. Humans can study, observe, query and test models and systems that unfold their behaviour in a computer. Repeating the simulation runs across a range of values for selected variables can give insight into system behaviour and its dependency on initial conditions and its environment. That, in turn, allows the user to draw conclusions about the reality modelled that can be tested in practice and can guide decisions.

If the process of developing a sufficiently sophisticated model, acquiring data and programming the computer is faster than reality, then prediction is possible. This notion is of critical importance as the measurement of a complex reality can require rebuilding that reality in a model and playing with it to study its behaviour – in the words of Nicholas Negroponte, founder of the MIT Media Lab: "*don't dissect the frog, build it*"[3]. In that sense, for a complex system, simulation can be measurement.

For that way of measuring a complex system to be useful, it must deliver its results in time for analysis and action to use them. Depending on the lead times required for analysis and action, that can require measurement to be faster than the reality measured hence, ideally, measurement should have the speed to be predictive. That involves trusting the model sufficiently for the purpose.

Many variants or configurations of a model and the systems that make it up can be used to generate scenarios of how the model behaves and evolves and to represent future states of the model. Humans can compare the scenarios and states generated by running simulations on a model with observed reality. A Monte-Carlo approach of calculating "possible future histories" of the model can be used to assess the likelihood of given scenarios and outcomes occurring in the future. Timely availability of such information can be invaluable input into analysis and decision-making.

Reality is always far more complex than any model hence the predictive power of a model is limited. At best, its validity extends until the point at which the (cumulative) influence or effects of factors not covered in the model become significant. For instance, the validity of predictive power in finance might stop where panic of large human groups begins.

It is safe to assert that simulation can allow us to query in a consistent and possibly precise way many aspects of the current configuration and the instantaneous trajectory of reality as modelled. That can be very useful input for further analysis of a complex reality.

System design and model design drive and constrain measurement performance and predictive power

Design of a system includes choices on parameters such as:

- the number of elements,

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[3] https://www.wired.com/1994/07/negroponte-4/

- the granularity / size of the elements (level of aggregation),
- the coverage at system and model level (area covered; coverage density: sample or census),
- the precision and detail of element description.

Design needs to find the right balance between:

Sophisticated enough	Vs.	Simple enough
• To be fit for purpose		• To be feasible
• For sufficient time horizon		• To be computable
• For flexibility / versatility		• To be affordable
• For reliability		• To be fast enough
• For detail of output		• To be understandable
		• To be trustworthy
		• For timely data availability

Figure 3 provides an illustration of some of the limits that constrain the size and design of a system or a model and how they interrelate.

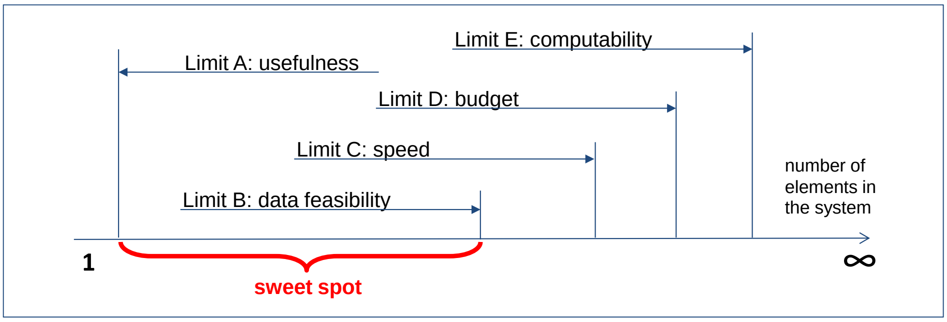


Fig. 3. Limits that constrain the size of a system or model

Limit A expresses that a system or a model can be too simple to be effective. Limit B expresses that beyond a certain size, the required data sets cannot be collected at sufficient quality. Limit C expresses that beyond a certain complexity the development of a system and its data collection might simply take too long. Limit D and Limit E are self-speaking. There might be more limits of significance hence this quick analysis can be refined.

If a useful size of system or model can be achieved with resources available, there is a sweet spot within which the designers will be able to work.

The recent years of globalisation and digital revolution have shifted those limits in finance and the economy. The shifts are different for each limit, which has an impact on our capability to design systems and models for useful measurement of finance and the economy (figure 4). Hence the sweet spot has changed. A quick assessment of the shifts on the limits represented in the graph shows that:

Limit A: This barrier has shifted towards a much larger minimal size of models. Measurement and analysis of complex, turbulent markets require consideration of objects and interactions at micro level; simplification to a few aggregates doesn't support understanding modern markets. Moreover, the relevant market for most kinds of analysis is now at least international. Much larger systems / models are thus needed. Much larger amounts of more granular data must be computed to simulate more turbulent situations on a larger scale. That development is reflected in many of the global, large-scale, transaction-level and near-time data collection processes that have been launched post-crisis by regulators under the aegis of the Financial Stability Board and the Basel Committee.

Limit E: Computing power and storage capacities have increased tremendously and continue to grow fast.

Limit D: Even if budgets for measurement (traditionally the Statistics function) didn't rise substantially, they now reach much further in terms of the computing power and storage capacity the same budget can buy, at least for hardware. On the other hand, the cost of designing and operating larger measurement systems has gone up, also due to the challenges of designing such measurement systems around around large-scale data with serious, often size-induced quality flaws (e.g. non-standardisation across data collected from many sources).

Limit C: Data collection might have accelerated, but technology and the real-world markets have accelerated more. On balance, challenges in system design might even have pushed that limit down.

Limit B: Data feasibility (availability, quality, timeliness) has progressed, but at the same time needs exploded and sources multiplied, leading for instance to "mapping hell" where many data sets need assembling into a larger one and/or to low quality when data collections were launched with insufficient preparation.

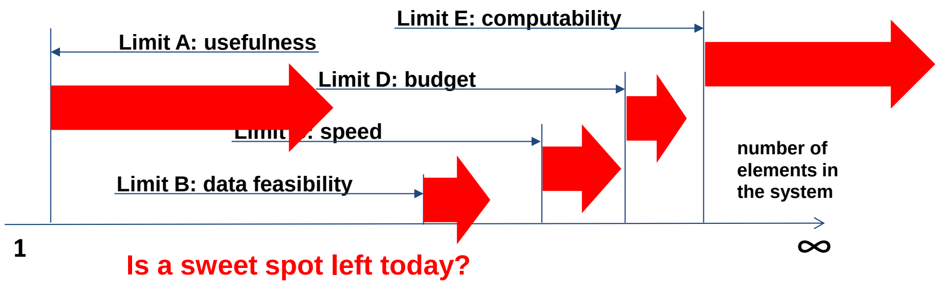


Fig. 4. Limits that constrain system design capability are shifting

The question arises, whether there is a sweet spot left open for design or whether it is closed (at the moment or for good), That question is pertinent because the same technologies are being used on both sides of the barrier, creating the challenges and responding to the challenges. However, there is an asymmetry: the use of techonolgy that creates the challenges is far easier than the use of the same technologies to address those challenges. A business that sets up a automated trading system needs to design it for its own performance only in a limited environment (business and legal) whereas measurement for policy-making must encompass all those businesses' activities and evolve alongside their diverse innovations, often in a complex environment involving many legal and institutional barriers.

That can leave authorities in a situation, in which some policy goals cannot be executed technically, i.e. their implementation could be ineffective. One clear strategic goal could be to re-create the conditions for effective implementation of policy-making and/or its implementation. Systems built without necessary conditions being fulfilled should be exposed as ineffective as soon as tested by a real crisis.

For complex systems, simulation is measurement; it supports analysis

In the context of a control cycle, people conducting the analysis (should) play a role along the whole supply chain leading from the reality being observed through measurement to analysis. They (should) contribute to the design of the model selected for measurement and analysis, thus influencing the selection of systems to be considered for data acquisition and model building. Analysts (should) advise on and accept the data to be collected and used, and they (should) suggest configurations and scenarios to be explored (figure 5).

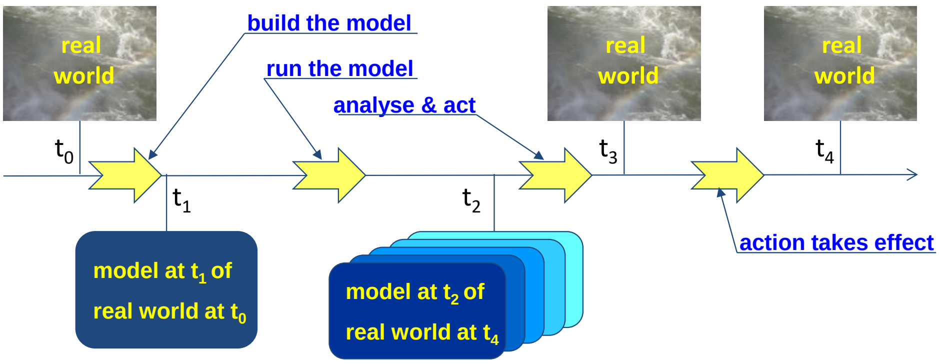


Fig. 5. Control cycle stages

However sophisticated a model is, it only supports analysis. Simulation is closer to measurement; it cannot be the analysis. Analysis draws in more information than the outcome of a simulation conducted on an approximate model can provide. It also includes all aspects of reality not covered by models used, including many qualitative ones.

Analysis can feed back into measurement. It can raise questions and highlight issues, some of which can be tested through tailored simulations. That way, consistency with the model can be better understood, system behaviour can be gauged and some of the analysts' assumptions can be tested. Simulation-based measurement can enrich analysis by revealing effects, behaviours and correlations. Especially when dealing with complex systems it can deliver counter-intuitive insights that a human mind wouldn't necessarily generate on its own.

It thus seems that dialogue between analysts and the statisticians, modellers and data scientists could be indispensable for adjusting measurement of a complex system to the analysts' needs.

Dialogue around model- and simulation-based measurement is likely to be richer than the dialogue around plain statistics; it can grasp complex behaviours and analyse many scenarios in a way plain statistics cannot. Hence model-based simulation can be seen as a more sophisticated form of measurement, i.e. of statistics.

However, same as for statistics, the value of a model depends on the quality of the data used. It also depends on the complexity, cost and speed of designing, programming and testing the model and running the simulation process.

Uncertainty is at the heart of every decision. Good measurement should minimise uncertainty.

Just as measurement is not analysis, analysis doesn't make decisions; it doesn't act. Analysis helps identify and assess options, ideally much of it in a rational, technical way. Analysis builds on measurement, and in the case of complex systems, analysis helps shape measurement. Decision remains purely human, a choice that involves elements beyond purely "rational", once rational analysis is exhausted and has prepared the decision-makers and actors to take the plunge into uncertainty. Every decision, also in policy-making, is ultimately a product of "informed instinct" and a move in a complex game with other actors who do the same. Often enough, decisions need to be made under time constraints, in the face of surprises.

Measurement and analysis must strive to minimise the need for decision-makers to take risks. The mission of measurement is to provide all the factual information that can be obtained about reality. The mission of analysis is to exploit that information to carve out possible courses of action and help decision-makers to assess their possible outcomes.

Every opportunity to do so that is left out by measurement and analysis adds to the uncertainty the decision-makers face, hence increase the riskiness of their decisions.

Fast change in the substance of the reality managed by the decision-makers creates new needs for measurement on the one hand and new means for it on the other. Finance and the economy have seen their substance change particularly fast over the past few decades, driven by technological progress that has ushered in globalisation and digitisation.

It is time for measurement to catch up with the new needs that arose and with the new means that appeared. Obsolescence is the alternative and more uncertainty in policy decisions would be its consequence.

4. Towards a vision and strategy for better financial & economic data

The abstract considerations above and those that follow might come as somewhat strange to many a reader who spent years working on the theory or practice of finance and the economy, of statistics and their analysis. However, that path is chosen consciously to open space for creativity, by allowing an escape from the gravitation of established language and the traditional concepts it carries. The excursion into "naïve" language reflects an attempt at establishing conditions to facilitate the generation of new ideas. It is intended to enable a path to new concepts that might give us a chance to respond to the profound disruption to our collective behaviour that comes from the "digital explosion" and that affects finance, the economy and politics among many other fields. Examples of that disruption abound for whom looks that way, among the latest being the intensive and innovative use of social media that is said to have revolutionised the conduct of recent electoral campaigns.

One intended outcome of that work is the design of a concrete vision that will support the creation and acceptance of strategies and of practical initial steps along a development path towards better data for keeping the stability of finance and the economy under control.

Two visions of the global economy and finance

In a very schematic view the economy and finance encompass a subset of interactions among humans, involving activities such as producing, consuming, buying, selling, borrowing, lending and investing.

Lately, networked computers and faster, cheaper transport enable strong and ongoing reduction of spatial constraints on economic activity. For ever more people interactions become increasingly independent of geography; schematically, anyone can now trade with anyone else, anywhere, in real time. From that perspective, formal economy and finance can be seen evolving towards a single, global network of agents linked by contracts, supported by global networks of computers and transportation.

Before that evolution set in, one could view national borders as containing nearly closed economies and financial systems. International trade and investment could be viewed separately. That naturally led to the vision of the global economy and finance as a set of closed systems, the national economies, with international trade and investment as perturbation.

The validity of that vision has been eroded as technological and political evolutions made economic and financial activity more independent from spatial constraints. Taking that evolution to its logical end suggests that one could view the economy and finance as a global network of contracts connecting a global population of economic agents, irrespective of national borders.

Two vision of finance and the economy are defined:

<u>Vision 1</u>	**<u>Vision 2</u>**
A set of **Closed Systems** (national economies) with **Perturbations** (international trade and investment)	A **Global Network** of **Contracts** among a **Global Population** of **Agents**

In the sense of the term "vision" introduced above, akin to the notion of "world view", both visions are equally valid. Adopting the one or the other can be the result of a personal taste, or a technical choice driven by how useful the one or the other vision is for the purpose envisaged. Measuring the economy and finance is a complex, multifaceted endeavour. For some parts, the one vision might be more useful than the other. A rational observer might adopt Vision 1 for one task and Vision 2 for another task, according to utility. Playing between several visions can open more possibilities, especially when it is done through conscious choice.

Vision 1: Closed systems with perturbations

This vision is baked into economic theory and analysis, and in the legal frameworks and the standards underlying economic and financial statistics, such as those on national accounts, balance of payments and foreign direct investment. Measurement of finance and the economy under Vision 1 can be characterised in a few quick points:

- It accommodates diverse local statistical and data practices
- Aggregation works in successive stages, from local to national, regional and global
- Global groups & supply chains are broken down in national chunks and aggregated up again

- It is slow and inflexible, especially versus many needs that appeared during the recent crisis
- It offers limited analytics (e.g. drill down, views on global groups, markets, processes)
- Parts of it decay as perturbations through international trade and investment grow, i.e. with globalisation & digitisation
- It is here to stay for a long time, as most of our world is built on it.

Vision 1 could be seen as inherited through evolution from the pen-and-paper era, when data was technically slow and expensive to handle, whereby data volumes had to be reduced at source, and when the world was largely local and activity slow enough for humans to perceive, analyse and act upon.

Heterogeneity of the real world is reflected under Vision 1. Measurement under Vision 1 worked in the past and continues to work reasonably well for financial and economic activities that are sufficiently slow and organised along national lines. However, for activities that unfold with little regard for national borders or at higher speeds, measurement conducted under Vision 1 suffers.

Vision 2: Global network of contracts

This vision comes to mind under the impression of the digital revolution and the emergence of global corporations and global supply chains. It is not yet supported by much measurement in practice. However, many of the post-crisis regulatory efforts have recognised the need to build measurement capabilities that are de facto compatible with Vision 2. Measurement of finance and the economy under Vision 2 can be characterised in a few quick points:

- It considers a global population of agents and views contracts as relationships among those agents
- Conceptually one could imagine it covering the whole formal economy and finance
- It requires globally standardised identification of parties and contracts
- It could deliver a globally standardised resource of granular data maintained near time
- It could allow multiple aggregations: national, corporates, markets, contract types, etc.
- It promises in principle fast, flexible drill-down and analysis, and timely reaction to surprises
- It might require re-thinking and adjusting some of the legal environment, especially on confidentiality
- It is suited for serving a global, digital environment
- It could start from an easy core and grow in depth and coverage as the world adjusts

Vision 2 is inspired from the new reality where technology has taken out technical limits to handling data and the world is more global and can be faster than humans can perceive, analyse and act.

Fast, integrated measurement seems possible under Vision 2; yet culture change and technical learning are needed to implement the infrastructures and conditions required.

Vision 1 and Vision 2 seem to be at opposite ends of a paradigm shift.

A long transition might be expected, and not everything might (need to) move

Whereas some statistical functions might be revolutionised by vigorous progress in the sense of Vision 2, many other statistical processes might remain unchanged for a long time.

One possible dividing line between statistical processes suited for Vision 2 and processes better suited for Vision 1 would be between factual information, better suited for a Vision 2 approach and more sophisticated information, which would be better suited to Vision 1.

Finance and the economy are abstract systems made up of abstract elements that exist mainly in the heads of the parties concerned, on which there can be agreement, disagreement or misunderstanding. In such an abstract context, factual information could be described as information on which there is explicit, society-wide consensus. Such consensus can arise from law. If the law of a country establishes the existence of an entity, an asset or a contract, it gives that abstract object a near-physical quality of reality that makes that object a "fact". One could then posit that in a global perspective, an object is real anywhere at global level as soon as it is recognised as real by at least one legal system. More precise terms, an object that is recognised as real by one legal system is real everywhere in the world where that legal system is recognised. The fact that legal systems map the world with little overlap makes that concept possible. Factual information of that kind could in principle cover the universe of contracts and parties to contracts, enabling the notion of a "skeleton" of finance and the economy that will be looked at more closely below.

More sophisticated types of information cannot be given the same degree of reality, cannot be "facts", for instance because different individuals or groups might see things differently and there is no consensus created by law. Examples can be found in the notion of value or in information representing complex concepts subject to interpretation, as in accounting. Those more sophisticated types of information could be seen as the softer tissues that surround the "skeleton" of facts, making up the entire body.

Some measurement processes would probably combine components built under Vision 2 with components built under Vision 1. The simpler but factual, i.e. consensual, skeleton information could play a decisive role in organising the more sophisticated information.

Systems built under Vision 2 could be imagined to gradually gain ground in the private sector and in the public sector, as feasibility increases and benefits vs systems built under Vision 1 become visible. Such a shift might also be driven by increased needs for performance that could not be delivered anymore through further improvements of systems built under Vision 1. However, it is useful to caution that whereas the application of Vision 1 can be done by a single country on its own, the implementation of systems under Vision 2 require cooperation among countries, ideally at global level. Considerations above also imply that systems based on Vision 2 might be limited to the realm of “factual” information based on the social consensus established by law; that realm might grow in the future but is limited so far. That realisation suggests exploring strategies that would aim to respond to the needs and interests of stakeholders that act at an international or global level, such as large corporates and international public sector institutions. One could also explore strategies to spread the realisation that in a globalised, digitised world, local financial and economic developments can be better understood and influenced when taking into account the global financial and economic ecosystem.

Vision 1 and Vision 2 imply very different concepts for measurement

Measurement would be conducted very differently between Vision 1 and Vision 2, as is illustrated in the figure 6.

Measurement designed under Vision 1 builds on local measurement performed within each one of the closed systems of the set considered, and it operates through successive aggregation of local results along a hierarchy of closed systems up to a national, regional or even global level.

Measurement designed under Vision 2 would start conceptually from a single representation of the entire global network of contracts, at element level (i.e. each party, each contract) without regard to local constituencies. It then produces information relative to a sub-system (country, corporate, market, etc.) from the sub-set of information relevant to the sub-system concerned (e.g. all parties members of the sub-system and all their contracts). That suggests the need for a global, element-level micro-data resource.

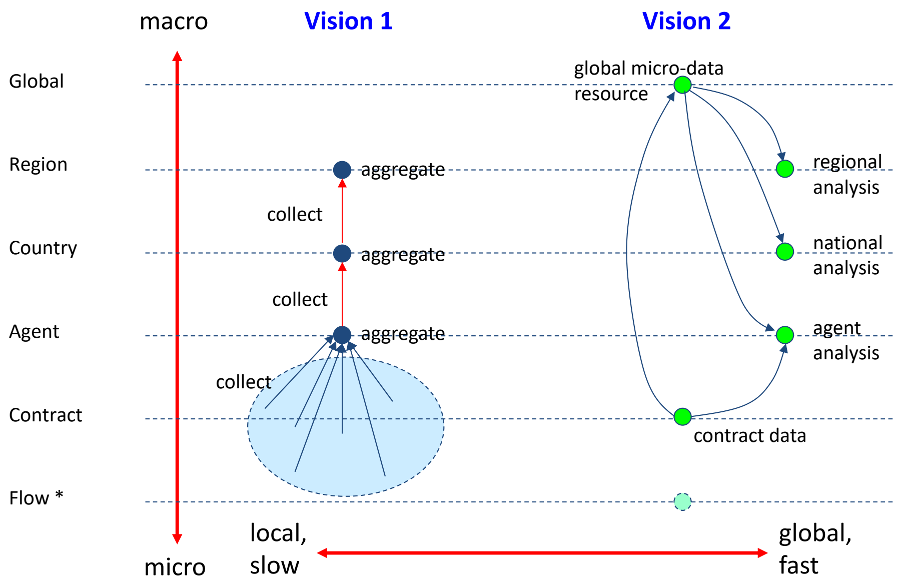


Fig. 6. Measurement in vision 1 and vision 2

The graph above suggests that the measurement of local and slow parts of finance and the economy could continue working under Vision 1 as it has in the past, whereas the measurement of fast, global parts should work better under Vision 2, if a suitable global micro-data resource can be built and the data collected and computed in time. It also suggests that macro-measurement derived by governments, corporates or other actors from the same global micro-data resource would have a greater chance of being consistent among them, which could be beneficial in cases where policies designed by institutions in several countries to address a large-scale situation must be aligned to succeed. That could also help behaviours to align for more stability, for instance across all participants in a market as they better perceive the actions of others and the configuration of the total group.

Measurement under Vision 2 seems also well suited for measuring processes or structures whose reality pays no regard to traditional subdivisions reflected under Vision 1. One example is found in the Sturgeon Report[4] large multinationals and the complex, global supply chains with flows of goods and services, and financial flows that form complex global webs, spanning many corporates.

Measurement under Vision 2 also seems suited to supporting the measurement of complex processes and structures spanning many countries and companies, also when things accelerate, as it allows envisaging implementation in a technologically uniform

4 (http://ec.europa.eu/eurostat/documents/54610/4463793/Sturgeon-report-Eurostat) The Sturgeon Report was commissioned by Eurostat (European Commission) and published in 1993

infrastructure that wouldn't reproduce in its processes the fragmentation and barriers baked into Vision 1, or the cultural and political barriers that come with them.

An example of possible analysis under Vision 2: the "economic footprint" of an agent

In the network of contracts represented by the Mechanical Skeleton of Finance, each agent is linked to other agents through a range of contracts. The set of all contracts entered into by an agent and the population of agents attached to them represent the primary economic universe of that agent, its contractual footprint, degree 1. Each agent in the population connected to a given agent A has such a footprint of their own; all those footprints, taken together, represent what could be called the secondary economic universe of agent A, or its contractual footprint, degree 2, and so on.

Execution of contracts in the primary footprint is important for Agent A as failure of a counterparty of Agent A to execute a contract can endanger Agent A. Likewise, failures two or more contract steps removed from Agent A can also affect Agent A. That concept suggests a possible way to formalise the notion of "Exposure". Besides, it also suggests the notion of "flows of liability" through the network, which could be analysed and represented, for instance for concentrations, turbulence, possibly also introducing a temporal aspect such as speed of propagation, as contracts can react with a lag. The potential for measurement through simulation in such a universe seems considerable at first sight.

That conceptual approach can be applied to a group of companies, for instance a banking group, where agent A would be the group's head entity. The banking group's footprint of contracts could be built in two steps. First the network of contracts linking up the entities that form the group in the definition chosen represents the group structure. Then the sum of the footprints of contracts of all entities in the group is added, representing the footprint of contracts of the banking group.

The same approach could also be used to represent the economic footprint of a country, whereby a central cluster of agents would be formed from government entities and agencies. A second layer could be made up of all people holding for instance a passport, a residency permit or a work permit that represent a contractual link to that government, and of all legal entities registered under laws issued by that government, equally a type of contract. Criteria can be defined at will by each user, building on any form of contract or combination of contracts, as analytical needs demand.

One could conceive building on such an approach a notion of statistical residency that would be technically rooted in formal criteria legally sanctioned by the government concerned. Today's definition of residency adopted in global manuals such as the IMF's Balance of Payments Manual, 6th Edition appear more judgment- and less fact-based[5].

[5] https://www.imf.org/external/pubs/ft/bop/2007/pdf/bpm6.pdf , page 70: "*4.114 An institutional unit is resident in an economic territory when there exists, within the economic territory, some location, dwelling, place of production, or other premises on which or from which the unit engages and intends to continue*

Such a definition of residence could enable more precise and flexible measurement of a national economy and its economic relations with other countries. Statisticians could define economic footprints suited to specific analytical needs, which might be different ones for instance for economic, fiscal, or social analysis. However, such a concept of residence could only work in practice if many other aspects of the statistical processes were to be transformed accordingly and built around the Global Micro-Data Resource introduced above. There is a long way to go, but the Sturgeon Report already suggested that overcoming the increasingly visible shortcomings of statistics on international trade would require an integrated international data platform (IIDP)[6].

In the alternative concept of measurement introduced in this paper, each economic agent, be they a single person or company, a corporate group or a government agency, could theoretically build representations of their relevant economic footprint from the same data infrastructure that represents the network of all contracts in the economy and finance. The same approach could be applied to the study of industry branches, economic sectors and the like, provided relevant classifications are attached to the entities concerned. The same approach could also be applied to the study of specific populations of contracts, for instance loans or derivatives.

The representation of an economic footprint is drawn from identification and summary description and classification data on each agent and contract represented in the network of contracts. Analysis of the economic footprint can involve the production of statistics or the simulation of scenarios on parts or the totality of the footprint, for instance responding to "what if?"-questions.

The approach could offer the advantage of improved consistency among analyses conducted by different groups. It could also allow distributed production of high-quality statistical aggregates.

A big advantage of the approach should be speed and flexibility that could perhaps match the demands on measurement of finance and the economy in the global, digital age. Moreover, it seems reasonable to assume that such a performance could not even be envisaged, and by far, for a measurement system built under Vision 1 – it would simply not be feasible.

Analysis can require more data on agents and contracts than what is held in the Global Micro-Data Resource. Limitations might arise from access rights to data and from data quality. There is a probably longer road to success, and it starts with first steps.

Designing a Global Micro-Data Resource

The broad outline of a global micro-data resource such as that suggested in the graph above can be deducted from considering the main constraints that apply. Although it is to be expected that such a resource would grow from small beginnings, a short utopian

engaging, either indefinitely or over a finite but long period of time, in economic activities and transactions on a significant scale."

6 Sturgeon, p.44

exploration helps to carve out the main constraints quickly for a first characterization of the resource.

1. In its ultimate development stage, the body of data held by the global micro-data resource would be very large and some of the computing using that data to produce measurement or analysis would require handling extremely large data flows. Hence:
   - The computing processes would need to be entirely automated and their output would need to be trusted by users quasi-blindly as there would be little scope for verification by humans.
   - Therefore data held in the global micro-data resource must be radically standardized as there will be no latitude for any quality improvement within the processing system.

2. The analytical systems need to deliver near-time results of high actuality if it is to be useful for measuring and analyzing fast developing global situations. Hence:
   - Data held in the global micro-data resource must be up-to-date nearly in real time
   - The global micro-data resource must be complemented by a system that supports quick programming of new, surprising queries, models and aggregations

3. The system needs to be welcome and actively supported by market participants as they would probably need to be asked to ensure that data related to their activities are maintained accurate and up-to-date at any time. Hence:
   - Market participants must enjoy immediate benefits from contributing to the global micro-data resource.
   - Those benefits can be built into the global micro-data resource if it holds the very data market participants need for their operations and if that data is better than what the market could deliver on its own.
   - Hence the global micro-data resource should be designed to be the operational data infrastructure of industry, especially of the financial industry.
   - That would in turn help industry to solve the growing problems it faces with its own data and with slow data standardization, which occasion high operating costs and higher-than-necessary operational risk.

4. The global micro-data resource needs radical standardization of the data it holds, much more radical and much faster than what the private sector left to its own devices and caught in a collective action problem at global scale could ever achieve. Hence:
   - Authorities must engage in standardization much more vigorously than so far, speeding up the standards development process and enforcing by law the standards needed for the global micro-data resource, once their design is agreed among industry participants. The established standards organizations such as ISO offer ideal platforms for broad dialogue towards such consensus.
   - Governments must come to recognize digital infrastructure as critically important to success, security and stability in the global, digital age and they must take responsibility for driving its emergence.
   - The move will be easier if the layer of data held in the global micro-data resource is thin, at least in the beginning.

- The move will be easier if it can start with fewer than all countries and progress to global coverage over time. Global industry should be expected to support global spread once benefits become visible.

5. The system needs to be affordable. Hence:
   - The global micro-data resource must be kept simple, at least in the initial stages.
   - It must contain data easy to maintain at high quality. That suggests holding in it data easy to agree on; the kind of data on quasi-facts, i.e. data that enjoys high social consensus, preferably anchored in local law, as described above. Ideally it would hold data free from interpretation, which could generate uncertainty expensive to correct.
   - It must contain data useful to all parties.
   - Identification and basic description of easy-to-identify objects, such as counterparties and contracts, could be a suitable type of data.

6. The global micro-data resource needs to be perceived by market participants as worth its cost. Hence:
   - Promoters must ensure that the cost of the system is also compared to the cost of not having the system.

7. Where benefits don't accrue to those market participants that bear the cost
   - Mechanisms must be sought that ensure the global micro-data resource is financed by participants that enjoy the benefits or, for some time, by governments or market authorities, for the sake of overcoming disputes that might be fruitless and delay implementation hence prolong the risks the resource should help address.
   - Should the global micro-data resource come to be perceived to be of high value and/or should it become "too cheap to meter", it might make sense that governments consider it to be an infrastructure to be financed centrally, saving the cost of collecting cents from millions.

8. The global micro-data resource must support flexible analysis, which can entail the need for quick delivery of additional data not normally held. Hence:
   - The global micro-data resource might have recourse to an internet-based system for fast ad-hoc collection of additional data. For instance, in case a specific type of security is at stake, each issuer of such securities would receive a link to a table representing the securities issued by them and the attributes required, which they would put directly into the modelers' and analysts' database.
   - Agents that would deliver in time might offer coverage sufficient for useful analysis. Those not delivering could be fined; their fines could be used to finance the system.
   - By the way, collecting data directly into a global database, as done by many businesses, might both be more efficient and faster, and deliver higher quality micro-data than collecting such data through technically unnecessary intermediaries such as "trade repositories" that introduce another layer of diversity in data that should be uniform.

Reporting directly from operational systems

A vast resource such as the global micro-data resource would never be built just to serve the specific needs of statistical or regulatory reporting. Market participants would balk at the cost and public sector institutions might have a hard time uniting around a common project of global reach. Hence the broad concept of organizing data such that reporting could be delivered as much as possible directly from operational systems could find higher acceptance.

Whereas such a concept might relieve reporting agents from some of the burden of having to produce secondary data for regulatory purposes, the main benefit for the private sector could well reside in reducing the operational costs and risks that come with exploding data volumes in an ever more networked business world. As time goes, industry and regulators could learn how to increase the share of reporting that could be delivered straight from operational systems.

A collateral benefit of reporting directly from operational systems could be found in speed, quality and and international consistency of measurement built on it and conducted under Vision 2. Whereas it is easy to imagine the potential benefits from such an approach, it is also easy to find the legal and cultural barriers that will need to be overcome on the way to its implementation.

A gap has opened between the demands on measurement of finance and the economy in the globalized, digital age and a heavy legacy of laws and habits that were built and entrenched over decades before that new age dawned so quickly. Whereas the perspective of having to close that gap can be daunting, some could conclude that it is less daunting than the perspective of not doing it.

Giving back value to agents burdened by reporting

The creation of a global micro-data resource as suggested here could also help delivering on a promise repeated many times by leaders of statistics, namely to give back value to the agents increasingly burdened by reporting.

If the global micro-data resource is built as the operational data infrastructure of the private sector, that promise would be fulfilled.

An opportunity for taking leadership and regaining the trust of people

During the crisis, market authorities and governments have lost some trust from the people. Decisive action on building together a global (or at least regional) digital infrastructure could be received as a positive societal project. It would reduce costs for the markets and reduce operational risks for businesses. It would also deliver the technical infrastructure required to produce the technical product "transparency", long promised, and especially since the 2007/08 crisis. It would also help to lift the effectiveness of the many good policy measures taken following the crisis, not all of which have reached effectiveness yet. For instance it could deliver credible progress on managing systemic risk, facilitate the resolution of large banking groups, or enable the construction of better large international financial registers.

Finally, strong public engagement in the construction of a digital infrastructure for finance and the economy would be seen by industry as a response to numerous calls from industry for public engagement in data standardization.

A possible starting point: the "Mechanical Skeleton of Finance"

Among the many systems one can identify in finance, there is one that is needed for nearly all models that build on micro-data and for nearly all business processes in industry. That system is the one made up of all market participants and of the contracts that establish and cement the economic relationships among them.

Each element of that system is anchored in law in its own constituency, which gives it near-factual quality of reality at global level, in the sense discussed above. In principle, that should make it easy to identify them in a unique, consensual way that could give rise to global data standards for describing them.

That system could be called the "mechanical skeleton of finance".

Some users might be happy with lower granularity and delayed data, but if the global micro-data resource is to become the operational data infrastructure of the private sector, it will have to hold data at the finest level of granularity and of the highest actuality, near or at real-time. Even if the development of the "mechanical skeleton of finance" might happen in steps over many years, that goal is inevitable, even if it might appear as a tall order, seen from today's perspective, We have no choice but to be ambitious.

Anatomy of the Mechanical Skeleton of Finance

The anatomy of the Mechanical Skeleton of Finance is sketched in the figure 7.

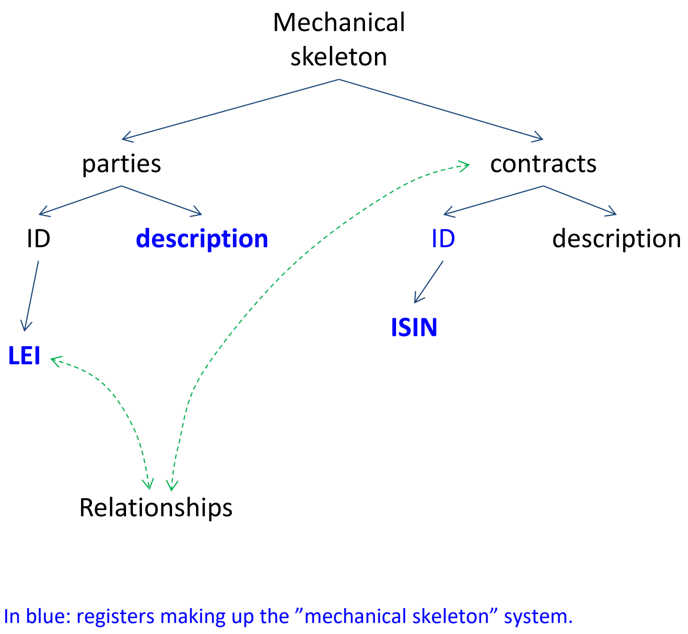


Fig. 7. Mechanical skeleton of finance

That graph suggests five major thoughts:

- A beginning is there. The Global LEI System (GLEIS) is up-and-running; it now offers the capability of identifying entities and describing them in a globally standardized fashion. Still, the GLEIS requires two main developments: (1) broader adoption, up to full coverage and (2) implementation of relationship data.
- The identification of relationships. One could consider that relationships relevant in a formal economy are mainly those embodied in contracts. That in turn suggests the possibility of using an instrument / contract identifier such as the ISIN code to identify relationships. Ultimately that could lead to the thought that the system that supports the ISIN code should be integrated into the governance, business model and organizational framework of the GLEIS and covered by future comprehensive digital infrastructure legislation.
- A solution is needed for a standardized description of contracts. The ACTUS project could be studied to find out whether the approach can hold its promise of a algorithmic description of contracts, which could also help solve some of industry's problems.
- It could also be studied whether the same ACTUS approach could be extended to non-financial contracts, i.e. contacts that involve not only cash flows, but also asset flows. A first attempt at generalisation is shown in the annex.
- To complete the Mechanical Skeleton of Finance, all agents capable of entering into contracts need to be covered by the system. That would ultimately include

individuals, currently left out of the GLEIS (with exception of those acting in a business capacity, e.g. as sole traders).

Ultimately, the Mechanical Skeleton of Finance could respond to the following description:

- Public good
- Global infrastructure
- All market participants registered
- All contracts registered
- Unique, standardized identifier for each item held
- Basic reference data included
- All data current and accurate
- All data maintained by market participants

Further steps:

- Each contract represented as an algorithm / a smart contract
- Extension to non-financial contracts
- Historical data (see below, transactions)

National legacy identification systems will thrive in the new global infrastructure

The emergence of a global identification infrastructure, with the Global Legal Entity Identifier System as its first implementation step, raises the question of the future role of the many existing identification systems that exist at national level.

The very name "legal entity" suggests that the existence of such an entity relies on law. Law cements social consensus for its whole constituency that a given entity exists and it gives it identity in the name of society. The legal act of giving identity is performed and documented by bodies mandated by law. Each legal entity in the world is thus given its identity and its legal form, which establishes the rights and duties of the entity, in the legal system, in which it is established.

The GLEIS has been designed to provide a globally standardised representation of the identity of the legal entities it registers. The GLEIS validates the identity claimed by a registrant entity against an official register in which that entity is conferred identity. The GLEIS thus does not confer identity upon any legal entity. Conferring identity upon a legal entity is a sovereign responsibility and will remain so.

That points to a continued role of the existing national business registers that might nevertheless experience change in at least two ways. First, in a country where several identification systems were created historically, e.g. for tax, customs or statistics, there might be pressure to rationalise the identification process within that country. Second, the local business register will need to move towards maintaining at least their core data in real time, so that businesses, both nationally and abroad, could rely on the national data and the GLEIS data for their business processes. Such development would make the incumbent business registers into infrastructures fit for serving society in the digital age.

A benefit for incumbent business registers could be in their gaining access to a global customer base who would be interested in buying information such as annual reports or financial statements that would remain at national level and not be displayed in the global public good infrastructure.

Legal Entity Identifier: universal coverage is not a new invention

There is debate about whether or not to mandate the LEI universally. All countries with legal systems in place that confer identity upon legal entities have made that choice many years ago. It can be seen as the very definition of a legal entity that it is registered in a national register established by law.

The question thus boils down to whether national law should mandate the use of a global infrastructure that offers globally standardised representation of the identity given by national law.

The G20 and Financial Stability Board have engaged in the creation of the GLEIS because they recognise the need for a globally standardised representation of the identity of legal entities across all countries in the world.

The very same reasons that led nations decide in the past that all entities in their constituency should be registered to facilitate both sovereign tasks and business do apply perhaps even more strongly at global level today, now that technology has made the world smaller and more interconnected than many a country was just a century ago.

The idea of taking the LEI to universal coverage at global level has been a tried and tested in many countries, for a long time.

A quick clarification: Transactions

Transactions play an important role in markets. They have not been mentioned yetin this paper. The Global Micro-Data Resource would need to hold historical data as well. That would include transactions. Indeed in the logic of this work, a transaction could be defined as the creation of a new contract or a modification to an existing one.

That definition of transactions doesn’t necessarily include the flows that materialise the execution of contracts, such as cash flows, asset flows or services being rendered, unless the execution of such a flow requires a specific contract, for instance with a service provider such as a payments firm. Such more technical contracts might be seen in a more refined version of the Mechanical Skeleton, i.e. in a later stage of implementation.

However, that definition would de facto make transactions part of the Global Micro-Data Resource and of the Mechanical Skeleton of Finance.

Public seed investment and the Transformational Power of scalability in data processing

An implementation strategy could build on the idea that seed investment would unleash transformational power in the private sector, mobilising the forces of industry to continue the work, once the avalanche of benefits has started to roll.

A major driver of such transformational power could be found in scalability of data processing that is likely to result from data standardisation. Indeed, today's messy data defeat many efforts at automation, making worse the burden of age-old layers of IT infrastructure that was cut and pasted haphazard in the course of mergers and acquisitions among businesses.

Significant progress on data standardisation, beginning with basics such as the Mechanical Skeleton of Finance could open the way to significant economies of scale, which could, in turn, drive structural changes in industry, as large service providers would form to deliver better service at a fraction of the cost of internal monopolies banks currently use. Such scaling would also improve performance and quality of service and unleash further transformations of the industry.

The experience of the automotive industry from the late eighties to the late nineties of the 20th century shows that once triggered, such a move can become extremely powerful and much faster than any observer would have expected ex ante. Indeed, the global automotive industry was revolutionized beyond recognition in the course of ten years, between 1990 and 2000. The supplier base went through two successive waves of reorganization within those ten years. First, some big manufacturers floated their entire components manufacturing base as unsustainable conglomerates, which were then carved out by large investors who reshaped them into more focused groups that became powerful suppliers and technological innovators in their own right. In the process, the industry was transformed from an oligopoly of highly integrated manufacturers surrounded by a cloud of component suppliers into a matrix with much leaner manufacturers on the one side and powerful systems suppliers on the other, changing the dynamics of the industry. The whole process happened without disruption to the industry's functioning and saw continuous improvement of its products all the way.

Time might be ripe for a transformation of comparable magnitude in the financial sector, under the double pressure of technological change and evolving regulation.

Decisive engagement of authorities in the construction of a global digital infrastructure could provide an opportunity for shaping such a movement while regaining leadership and reputation.

Rationale and ethics of intervention for statisticians

Statisticians could accompany the movement and adopt a new positioning for measurement in the digital age, evolving from a traditional positioning that could be described as “hunter-gatherers” of data into that of interdisciplinary “data farmers”.

In sum, statisticians could follow a strategy of improving measurement of the financial system and the economy by seeking to make them more measurable, also for all participants. Doing so, they would also help the economy work better and more safely. Operations would organise to generate and use the same data that feed measurement, straight from operational systems. Measurement would improve and gain in flexibility by moving data reduction closer to the measurement output; that would become possible through the use of standardised micro-data directly from operations, which would allow data operaitons to be scaled and automated reliably, in turn allowing statisticians to handle much larger data volumes in large-scale IT systems.

The logic of the control cycle introduced above applies to each agent and entity. Everyone has one or more control cycles to take care of. If all participants in the financial market and the economy who need to identify entities and contracts could avail of the same basic skeleton data, their measurement and analysis could perhaps be a little more consistent (figure 8). That could make the world a little safer.

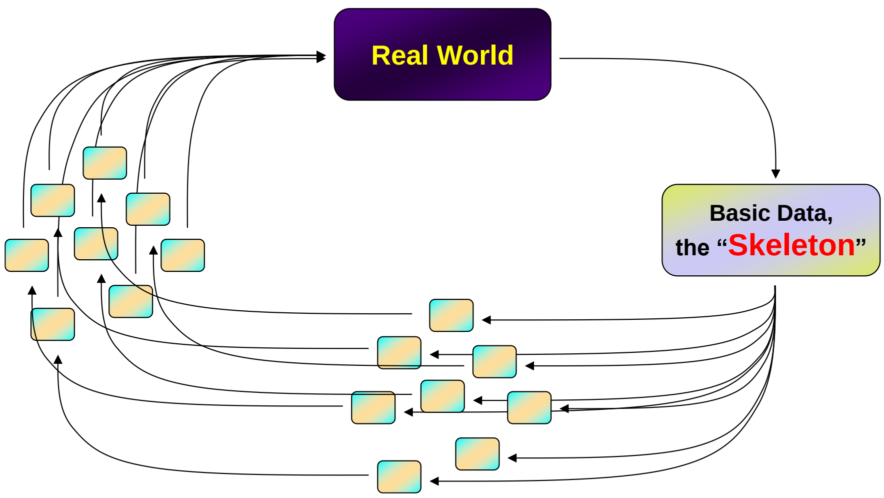


Fig. 8. Control Cycle and the basic skeleton data

Some statisticians seem to see an ethical barrier to such a shift in positioning, grounded in the classical wisdom that says that measurement should not influence the phenomenon measured.

Measurement, however, always influences the reality measured, as reflected in the ‘Observer effect’ in physical systems. One choice statisticians face seems to be between either influencing the system to make it more measurable, enabling better and safer policy decisions, or influencing it by delivering insufficient data too late when the critical moment arrives, thus increasing the risk of sub-optimal policy decisions. Measurement guides key decisions, shapes our world. For good or bad!

Hence it seems perfectly legitimate to consider strategies that influence the system measured to make it more measurable.

Additional specifications for economic and financial statistics

The new needs for measurement identified after the crisis and the data collections designed to deliver on them will generate new statistical products. Whereas those new statistical products will need to satisfy the existing specifications of official statistics, four new demands seem to add to those specifications:

- Global integration of measurement results as, de facto, technically, the relevant system measurement must capture is globally integrated as the Lehman crisis showed

- Speed of measurement near real time, as modern crises can explode overnight

- Nimble flexibility as modern crises are likely to generate developments not foreseen; surprises are inherent to any complex system and their properties must be measured as they appear

- Drill-down to specifics, fast. Specific, well-calibrated, "surgical" policy measures might require precise identification of the origins and mechanisms of a critical development. On the other hand, blunt policy measures might add to the problem.

Those specifications apply to the measurement of the kind of global, surprising and fast-moving crisis the digital age has enabled – possibly the most dangerous ones and the least well measured today. They also apply to the ongoing measurement of the impact and adjustment of remedial actions. They could also be useful in measurement that supports ongoing preservation of stability. Finally, they would help businesses improve their operational efficiency, reduce their operational risk and thus, indirectly, reduce systemic risk.

Overall, the goal of statistics remains unchanged: delivering information in a volume and shape the analyst's and decision maker's brain and models can effectively consume. In the context of the new needs that emerge along the technological revolution and that were painfully revealed by the crisis, the means to reach that goal need to be reviewed to fit the updated and evolving specifications.

The new demands represent a radical departure from some aspects of the traditional specifications that guide the design of statistics, suggesting that the usual means might not be able to stretch far enough. More radical innovation might be needed.

Now might be the time for embracing a new paradigm of measurement in finance and the economy and to draw the consequences for bold, strategic action; an ambitious goal indeed, but a sense of responsibility should urge us to take up the challenge. We stand at the beginning of a long, evolutionary journey. Like all journeys, that one will begin with a first step. Choosing that first step well will be a decisive key to success.

5. Conclusions

Technically, finance and the economy have become globally integrated domains of human activity. The ongoing exponential capability growth of information technology and the emergence of global networks have eliminated space as an impedance to speed and have enabled complex global corporates, markets and technical systems to develop. Markets and industries have become orthogonal to the states, to the legal systems and to the cultures that structure the human population.

Adequate measurement is a necessary condition for the control cycle “real world-measurement-analysis-action-real world” to work and for the preservation of stability where that isn’t built in. Adequate measurement must work at the scale and speed relevant to the system that must be kept under control. In the case of finance, the relevant scale is global, the relevant speed is real time, whether that is feasible or not.

Four additional specification for official statistics are suggested in view of these demands:

- Global integration
- Speed near real time
- Nimble flexibility
- Drill-down to specifics, fast.

A vision of finance and the economy as a network of contracts among a global population of agents is proposed as a platform on which to conceive a measurement system adequate for finance and the economy in the global, digital age.

A second conceptual notion that emerges is that of the “Mechanical Skeleton of Finance”. Leaving out the complexities of finance and the economy, the “Mechanical Skeleton” would encompass mere representation of the factual elements that make them up: agents and the contracts that bind them together. That concept brings to the fore the importance of identity in the creation of “facts” as social consensus on abstract objects, whereby law plays the role of engine of social consensus. It also suggests that global identification systems like the Global Legal Entity Identifier System merely offer a globally standardised representation of the identity conferred upon the abstract objects of finance and the economy by the laws of sovereign states.

Whereas the details of design and implementation of that measurement system are left to coming generations of statisticians who will have benefitted from learning along the path to come, first concrete, feasible steps on that path are sketched out:

- The need for a global, shared micro-data resource that would represent the "Mechanical Skeleton" and would be the operational reference data infrastructure of the private and the public sector

- The Global Legal Entity Identifier System can be the starting point for this global, shared micro-data resource. It must be developed to universal coverage, as a global infrastructure mandated by law in each country that participates in the global markets, each one of which already has recognised universal identification of legal entities as a necessity at national level.

- The public sector must engage decisively and invest to implement that infrastructure, as market forces cannot be expected to overcome the collective action problems involved in its delivery. It should be expected that once the infrastructure comes into place it will exert transformational power towards higher efficiency and lower operational risk across the private sector, leading de facto to a reduction in the components of systemic risk that are linked to loss of control induced by digitisation and globalisation.

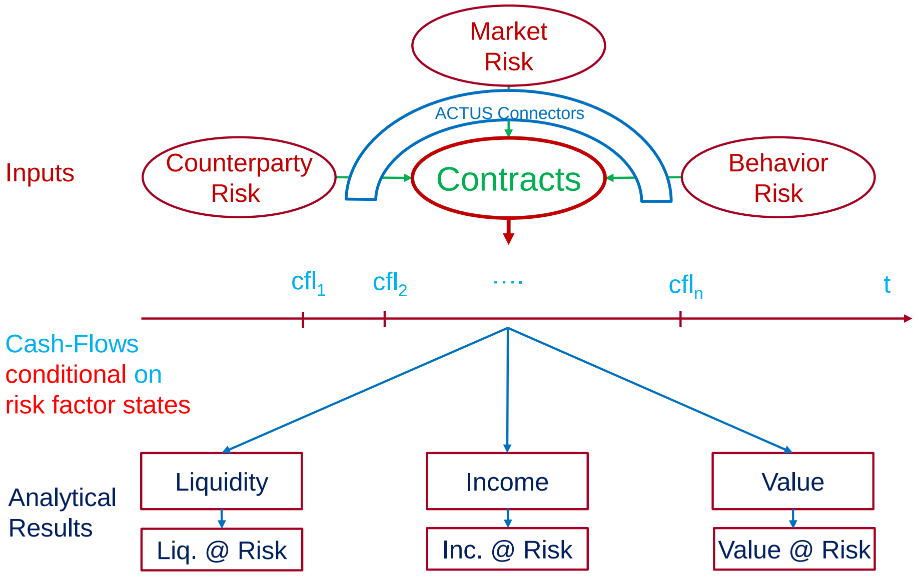
- For instance the infrastructure should be expected to facilitate the development of the operational infrastructure in industry such that reporting straight from operational systems could become possible, enabling measurement to fulfil the additional specifications of statistics mentioned above.

Finally, a plea is made for statisticians to recognise the need to move to a new positioning as interdisciplinary data farmers, helping to measure the world better by intervening to make it more measurable, building the artificial senses we need to stay in control of the dawning era of digital, global finance and economy.

Annex

Generalising ACTUS beyond financial contracts, and the ledgers required

The modelling logic of ACTUS is explained by the authors of the method in the graph below, extracted from the seminal book on ACTUS[7]. ACTUS stands for Algorithmic Contract Type Unified Standard. The ACTUS Project[8] has developed around 30 algorithmic models, each one of which represents a type of contract financial contract. The fundamental logic of the modelling builds on the notion that a financial contract can be represented as a mathematical function that determines "who pays how much to whom, when and under what circumstances". In that logic, the financial contract is represented by an algorithm that delivers a string of cash flows contingent on events the authors name "risks", a wording that reflects the origins of the idea, anchored in risk management. The same concept is explored in an OFR Working Paper by Mark Flood and Oliver Goodenough[9].



The intellectual property attached to the ACTUS project is harboured by the ACTUS Foundation[10] to keep it available for use in a public good such as the global micro-data resource envisioned in the body of the paper. In the concept of the "Mechanical

7 Brammertz, Akkizidis, Breymann, Entin, Rustmann, Unified Financial Analysis. Wiley, Chichester, 2009

8 See www.projectactus.org

9 https://www.financialresearch.gov/working-papers/files/OFRwp-2015-04_Contract-as-Automaton-The-Computational-Representation-of-Financial-Agreements.pdf

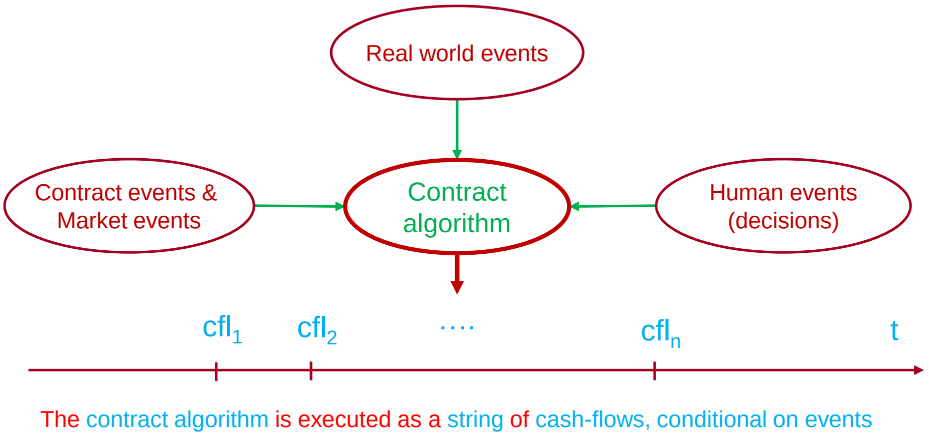
10 See www.actusfrf.org

Skeleton", ACTUS could be used to describe the contracts registered. It could also be envisaged to develop the ACTUS approach towards the notion of smart contracts.

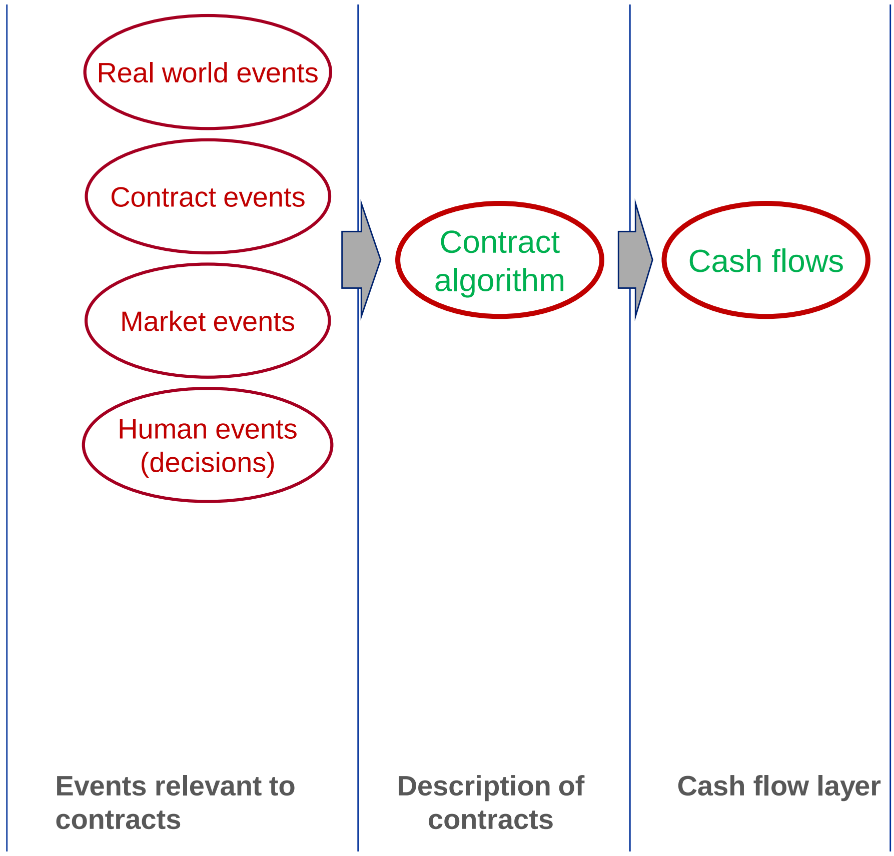
The present annex aims at presenting two ideas related to ACTUS: a generalisation of ACTUS to contracts other than financial contracts, and a notion of what ledgers would need to be created in the context of the use of ACTUS or a similar tool as an electronic representation of contracts in a global micro-data resource.

Generalising ACTUS beyond financial contracts

As a first step, ACTUS is abstracted to its core mechanisms and language is adjusted to more neutral and technical, away from the traditional language of finance and risk management.



The presentation is then translated from the above into another mode that can be useful for representing both a single contract and a population of contracts.

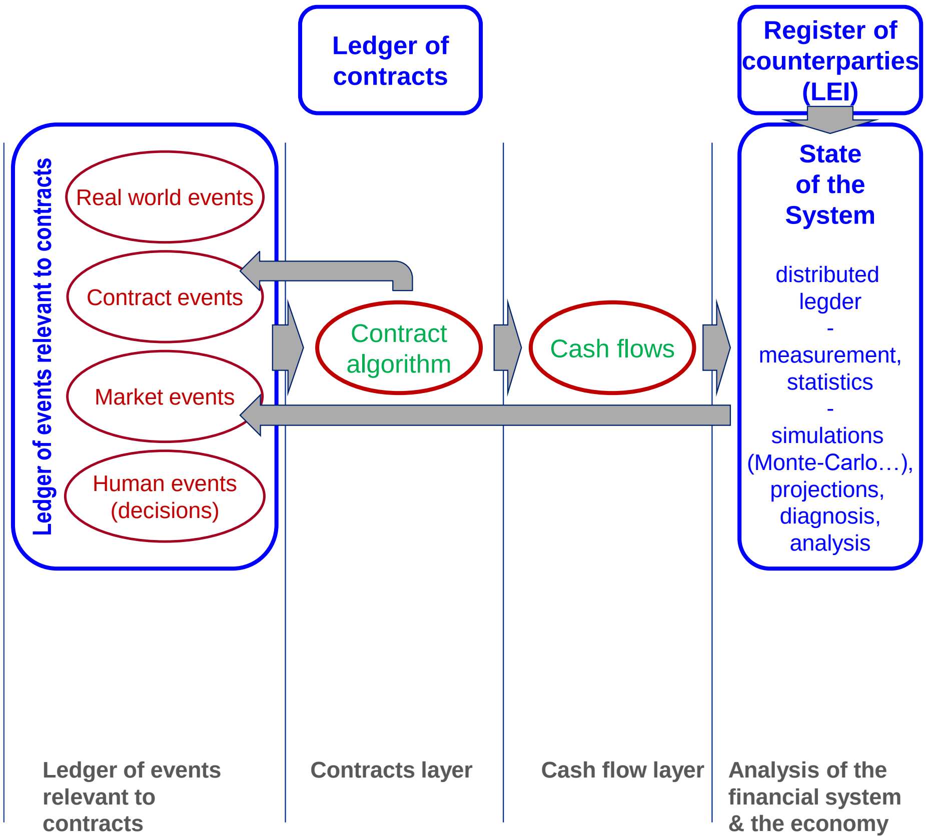


That representation is then used to present a population view of the system (see next page), including a layer for analysis of the financial system and the economy, where all cash flows generated by the entire population of contracts would be represented. The thought of using distributed ledger technology for that "state of the system" ledger comes quite naturally.

Tha analytical layer could in principle deliver all classical measurement data currently generated and used for the analysis of finance, such as official statistics. It could in principle do so faster and in higher quality than so far. It could enable drill-down so far not possible into usual aggregates. It could also deliver a host of further analytical material, flexibly, and at short notice, to help understand surprising events and scenarios as they unfold in the markets.

That analytical layer feeds back into the events layer, for instance certain configurations could trigger specific events registered in the ledger.

The model now also features a contract ledger, a ledger of events relevant to contracts and a register of all counterparties to contracts (potentially the Global Legal Entity Identifier System for all counterparties that are legal entities eligible for an LEI).



The ledger of events requires a special mention. The notion requires more work to define conceptually what it would hold. The broad idea is that any contract being driven by events that are clearly referenced in the precise language of well-drafted contracts, the events relevant to a contract can be identified and registered.

How to register a specific event related to a given contract remains to be studied in more detail. It could be limited to reference information and information about what states an event could take; the simplest being “has occurred” or “has not occurred”. Some events could be referenced in more than one contract, for instance “the first of the month has occurred” triggers instalment cash flows for probably millions of mortgage contracts. The occurrence of a complex event can be materialised by notification of a court decision. The ledger might not hold details of complex events.

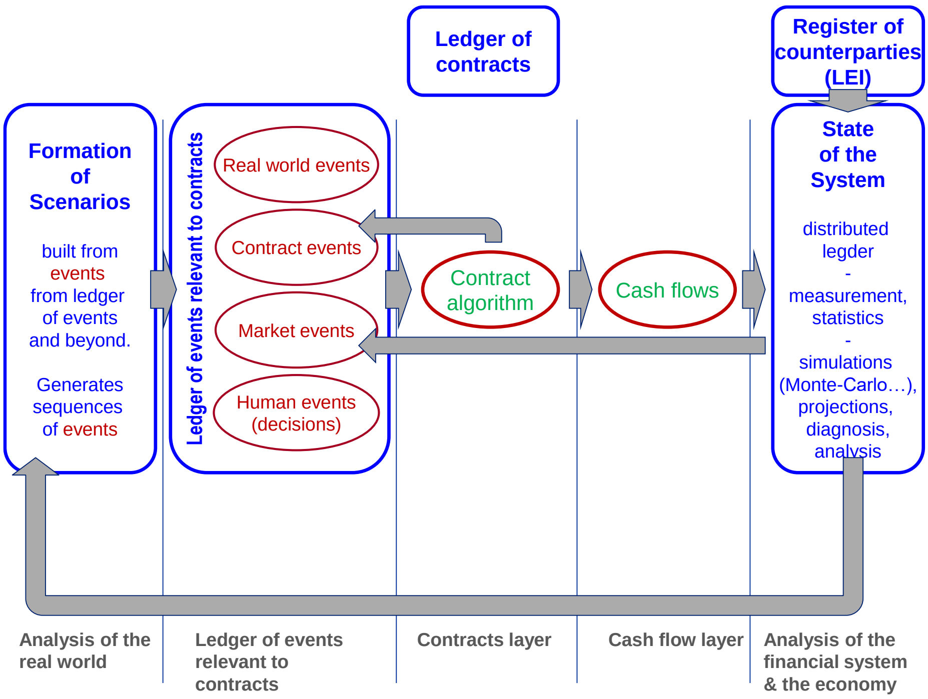
The system view is now expanded with a «real-world-analytics» layer that studies dependencies among a population of events that include events relevant to contracts and other events.

That is the layer in which market analysts, market participants and policy-makers form scenarios of the real world that will help shape their goals, strategies and actions.

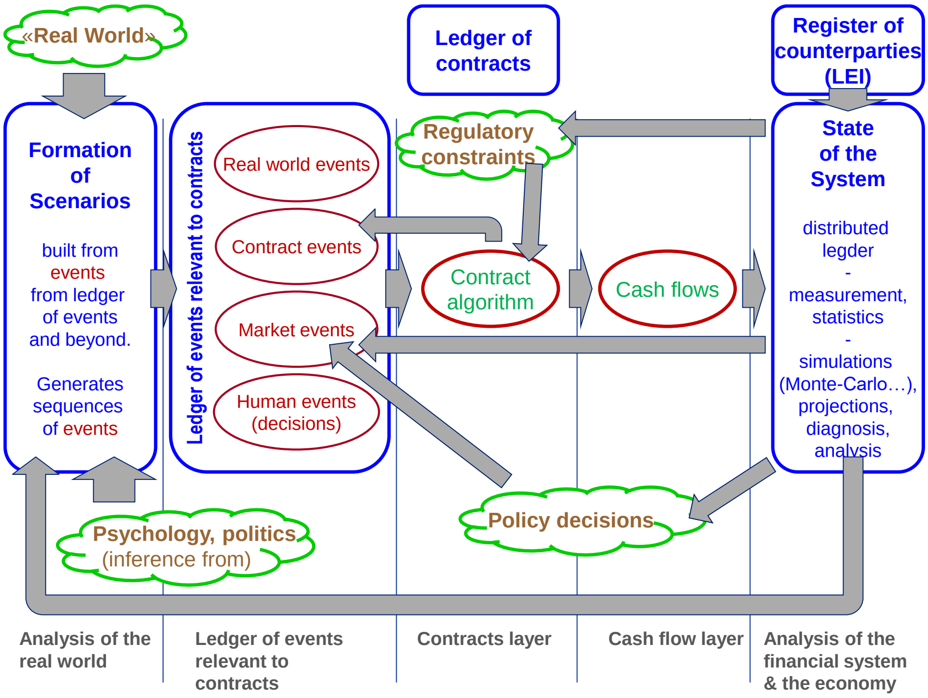
Work on that layer can take many forms, as it does today. It also offers an opportunity for application of advanced technologies, such as cognitive computing connected to the internet, e.g. «Watson».

Knowledge or assumptions about dependencies among events and whole scenarios can be held privately or shared publicly, as is the case today.

That view also shows that feedback from the «analysis of the financial system and the economy»-layer into the «analysis of the real world»-layer can be useful.



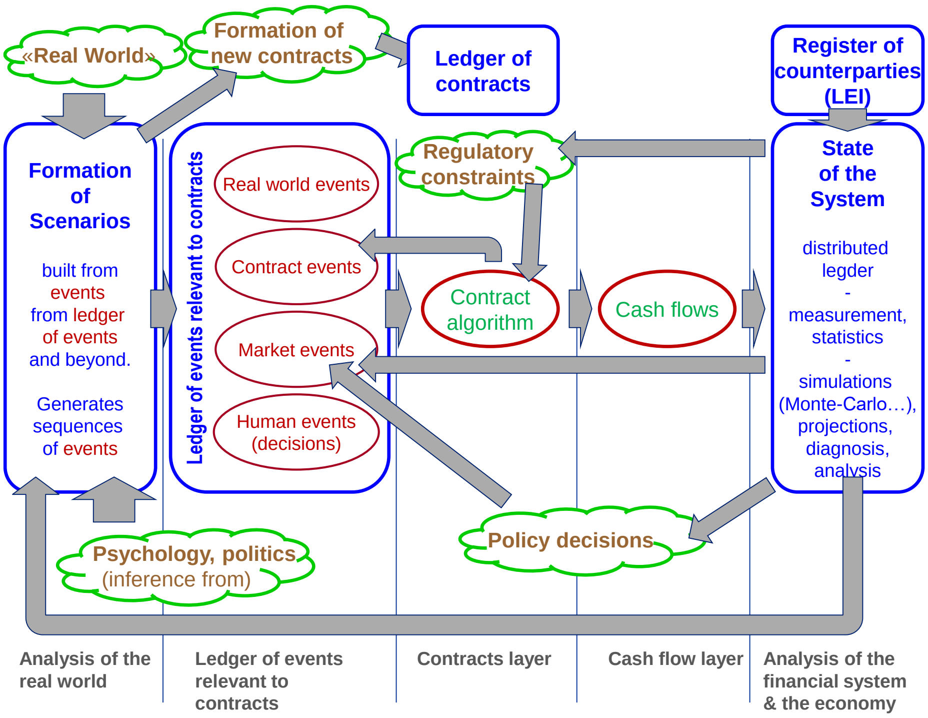
The system view is expanded again, now showing «exogenous» sources of information (e.g. observation) and inference that shape analysis. It also shows exogenous sources of constraints (e.g. regulatory decisions) on contract design and other components and practices.



The system view now includes the formation of new contracts entered into by market participants as their observation and analysis shows them trading opportunities

New contracts are added to the ledger of contracts. Changes to existing contracts can be subsumed in that category as well.

The creation of new contracts and changes to existing contracts can be called transactions.

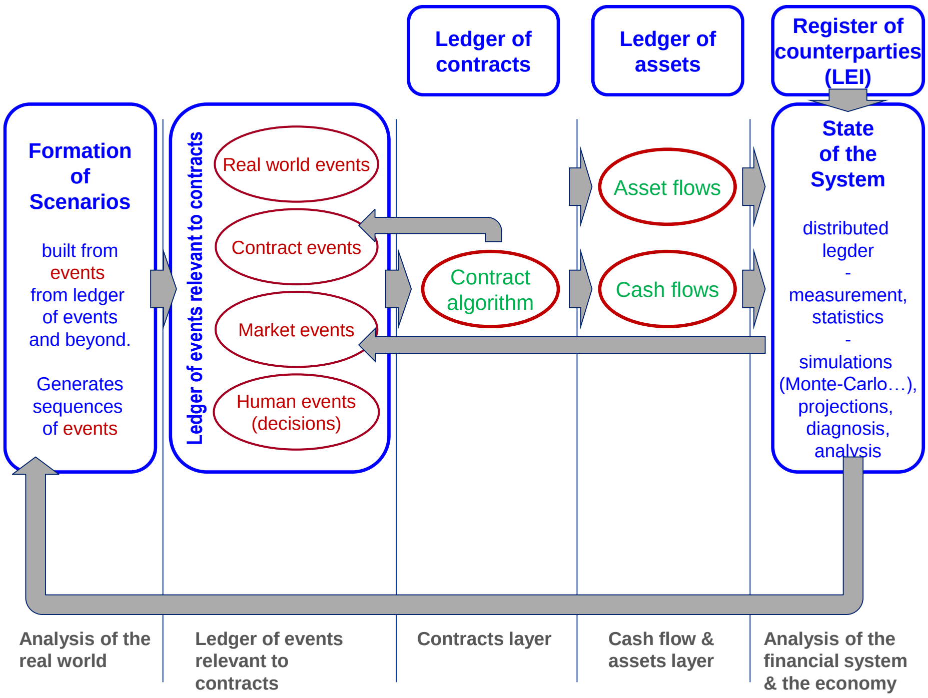


The system view can be enlarged to also include non-financial contracts that involve assets other than cash

In that expanded view, the ACTUS algorithm would deliver a sequence of «cash flows» and «asset flows»

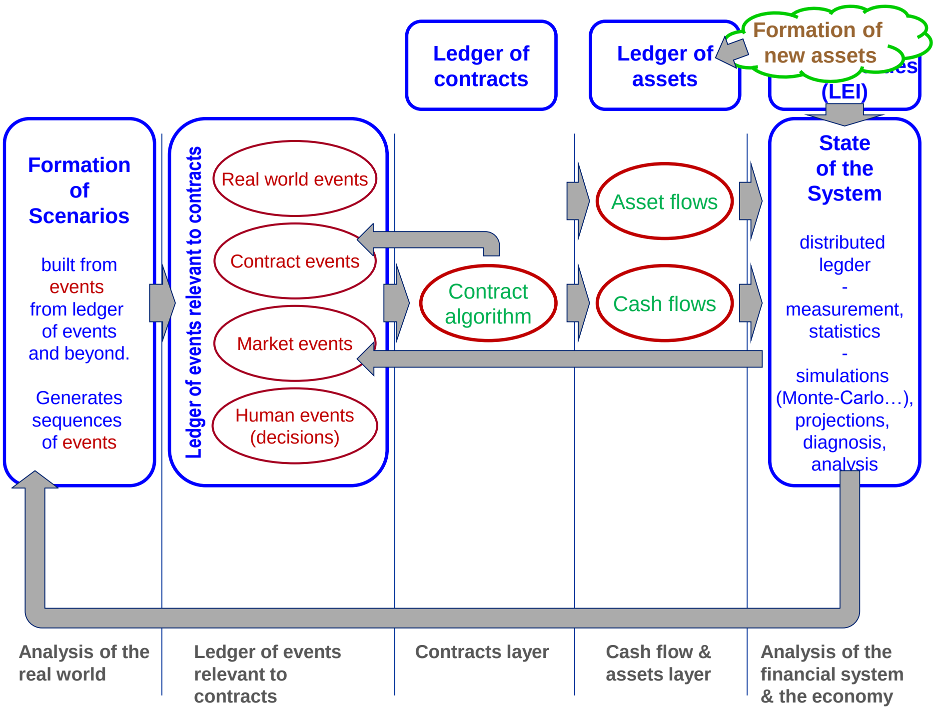
A ledger of assets relevant to contracts would need to be established. That ledger could also fit the concept of distributed ledger quite well.

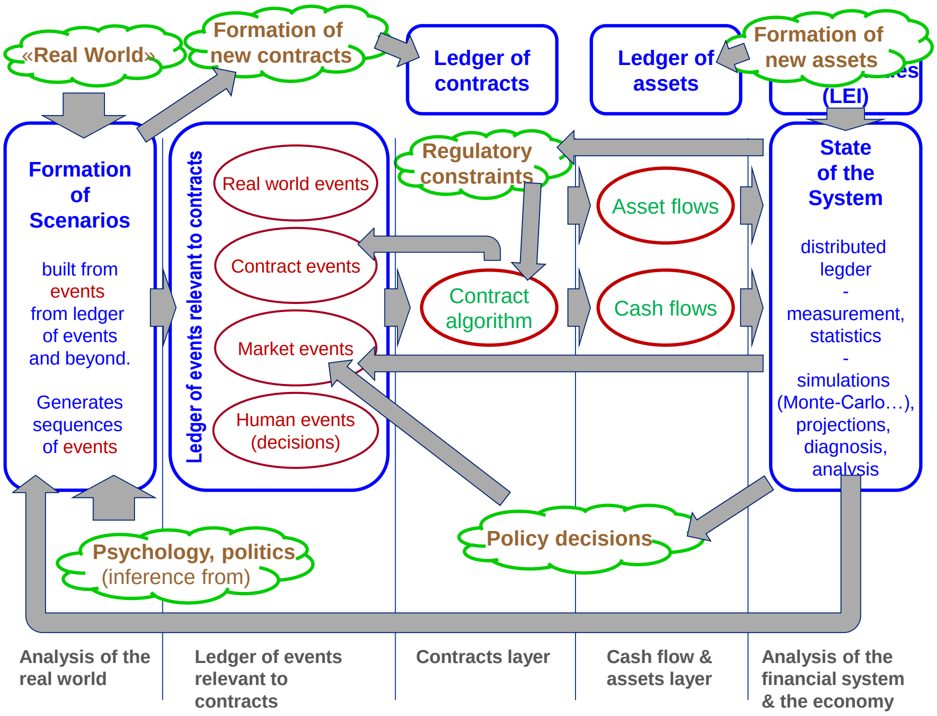
Events in the «analysis of the real world» layer could of course refer to assets listed in the «ledger of assets».



Enter another exogenous input to the system: formation of new assets

The formation of new assets and asset classes helps organise and steer human activity. Technical progress and constraints appearing in its wake can lead to the creatin of new assets and asset classes. Examples from the recent past include for instance tradable pollution rights and bandwidth licenses for mobile applications.




«Real World»
Formation of new contracts
Ledger of contracts
Ledger of assets
Formation of new assets
(LEI)
Formation of Scenarios
built from events from ledger of events and beyond.
Generates sequences of events
Ledger of events relevant to contracts
Real world events
Contract events
Market events
Human events (decisions)
Regulatory constraints
Contract algorithm
Asset flows
Cash flows
State of the System
distributed legder
-
measurement, statistics
-
simulations (Monte-Carlo…), projections, diagnosis, analysis
Policy decisions
Psychology, politics
(inference from)
Analysis of the real world
Ledger of events relevant to contracts
Contracts layer
Cash flow & assets layer
Analysis of the financial system & the economy

What ledgers would need to be created

The systemic view above aims to explore the possible shape of an integrated system of representations of objects relevant to the network of contracts as envisioned under Vision 2 in the paper. That exploration leads to define a number of infrastructures that would need to be built, which should be expected to take some time and to go in steps along a learning path.

Some parts of finance, some families of contract types, some geographical area could offer the opportunity of a more immediately useful implementation of such ledgers.

However, the aim of this paper is not to identify such fields. Much rather, it aims at laying out a way to structure the world we observe and want to measure in order to make it more measurable, building on the global network of contracts among a global population of parties envisioned under Vision 2.