European Commission

Modelling the EU Economy as an Ecosystem of Contracts

Volume 1 – Feasibility Study

EXRADE
January 2020

Justice and Consumers

EUROPEAN COMMISSION

Directorate-General for Justice and Consumers

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Directorate-General for Justice and Consumers
EU Justice Programme (2014-2020)

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Luxembourg: Publications Office of the European Union, 2020

PDF	ISBN 978-92-76-10638-8	Doi: 10.2838/28184	DS-04-20-084-EN-N

PREFACE

This is the first of two studies that together form a single project with the title 'Modelling the EU economy as an ecosystem of contracts'. EXRADE, Italy, has carried out this study with Luigi Telesca as lead author and coordinator. Contributing authors are James Hazard, Mahfuzul Islam, Ali Hassan, and Jukka Huhtamäki. Several people have provided helpful comments and suggestions as acknowledged in the respective chapters. In the course of 2019, the ideas contained in this study have been tested with academic audiences (Data for Policy conference at UCL, London; Annual Meeting of the Society for Economic Measurement (SEM) at Goethe University, Frankfurt), in a dedicated project workshop in Brussels on 30 September, a DG JUST lunchtime seminar on 22 October, and during a visitors' seminar at the Institute for New Economic Thinking (INET) at the Martin's School, Oxford University. Finally, the findings of the project were also presented in the poster session of the EU Conference on Modelling for Policy Support, which took place in Brussels on 26-27 November.

The need for this type of study has become stronger and stronger over recent years, as the economy rapidly transformed its modes of value creation in ways that are hard to capture with models and measurement systems designed for multi-stage physical production processes. As we tweeted at the launch of the call for expression of interest, we live in the digital age, but we continue to use models of the economy based on a 19th century view on economic life.

While mindful of the legal disclaimer above, we are encouraged by the findings of this first study. It provides a positive answer to the question if it is technologically feasible to model the economy based on contracts where machines increasingly perform the latter and results on those performances are increasingly communicated by machines to other machines (including virtual machines, i.e., machines made of computer code).

As digitalisation and automation continue to transform rapidly user experiences, justice and consumer policies accompany already the migration from a paper-based contracting environment to an increasingly digital, computer code driven contracting environment. However, not enough has been done so far to ensure that we preserve our ability to assess and evaluate justice and consumer policies in this rapidly evolving environment. Aiming to preserve and increase this capacity in the future are amongst the core motivations of the present project.

We would like to thank Luigi Telesca and his team for this high quality report, Paul Nemitz and Dirk Staudenmayer for their feedback at the stage of inception, and most of all Salla Saastamoinen, Director General (acting), for her unwavering support that made the project possible to begin with. We also extend our thanks to many colleagues in DG Justice and Consumers who have provided critical feedback via questions and comments directly rooted in their daily experience working on better justice and consumer policies for the digital age.

Harald Stieber, Project Officer
Dan Dionisie, Head of Unit, Economic Analysis and Evaluation

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1.1. Introduction

> *"We are moving from the old ways of measuring and reporting growth based on making and selling things (i.e., physical capital), rather than today's growth drivers of developing and creating human, intellectual, and network capital (...) Our research into business models clearly indicates a world where networks and digital assets are more valuable than things, and "access" is more convenient than ownership. In the process of creating more efficient, happy, and technologically supported lives, we may have to recreate how we gauge economic prosperity and growth."* (Libert & Beck, 2016)

With the evolution of today's economy from industry and manufacturing to services, information and networks, Gross Domestic Product ("GDP")[2] and similar economic measurement approaches struggle to account for the intangible structures and assets of today's economy. The modern economy is increasingly based on networks, services and insights. GDP and Generally Accepted Accounting Principles ("GAAP")[3] remain important measures, but fail to model increasingly important elements of economic activity and growth.

In a world dominated by the Internet and technology giants, a challenge for the European Commission and other policy and regulatory bodies is the fragmentation, inaccessibility of data and inconsistency of current indicators to support legislative and decision-making activities across a broad range of policy areas. In particular, assessing the impact of a change in rules can be challenging. As an example, some regulations impact the relative importance of some actors in networks because of a variety of reasons, such as competition or consumer rights. The changes and impact may be difficult to measure or predict using GDP since it does not integrate the wealth of data produced by networks and market structures, which are increasingly intangible and digitalised.

To create a better framework for policy making and monitoring, data should be leveraged and current economic indicators enhanced with network and "contract" information that better models the modern economy and provides a way to test and assess the impact of policies.

To achieve that, methodologies need to be updated and supplemented with new measures capable of real time mapping and monitoring of the relationships, networks, underlying structures and non-monetised transactions of the economy. The objective is to

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[1] This chapter was written by Luigi Telesca with contributions from James Hazard; the authors acknowledge helpful contributions on accounting from Stefano Federico (Studio Federico – Ordine dei Commercialisti di Roma).

[2] https://en.wikipedia.org/wiki/Gross_domestic_product

[3] https://en.wikipedia.org/wiki/Accounting_standard

make measurable and visible the way intangible assets and data should be accounted for in a European ledger of value.

In this chapter, we analyse:

- Weaknesses of GDP as a measure;
- The role of intangible assets and structures;
- How digital platforms facilitate the creation and transfer of intangibles,
    - the special role that Open Source has in this context;
- Difficulties in accounting intangibles following conventional accounting principles.

1.2. The Discontents of GDP

1.2.1. Origins

GDP is a measure of the economic activity of a State. It measures the final production (all final goods and services produced and traded) in a specific time period, in general the calendar year, by all economic actors. It was created by the economist Simon Kuznets for a US Congress report in 1934 as a way to measure national income (Kuznets, 1934).

Following a period of positive alignment between GDP and economic outlook, over the last 20 years GDP has been criticised by a part of the economic community (Hoskyns & Rai, 2007; Stiglitz et al., 2009, Costanza et al., 2009, Ahmad & Koh, 2011; Conway & Sturges, 2014; Coyle, 2015). The major criticisms are not addressed to the measure itself but rather to the way it fails to offer a clear view of current economic trends and growth, and its incapacity to measure things that go beyond the industrial "production" definition.

Policy makers have used GDP as a way to identify potential areas for legislation and regulation, and to measure the feedback in the introduction of new policies. GDP is aggregated vertically from individual transactions. It measures the reward to factors of production over a given time span, typically a calendar year. Unfortunately in the last ten to fifteen years, in the case of many policies that regulators have been working on, such a distribution of the economic wealth created in a calendar year has not been much impacted at all (Figure 1).

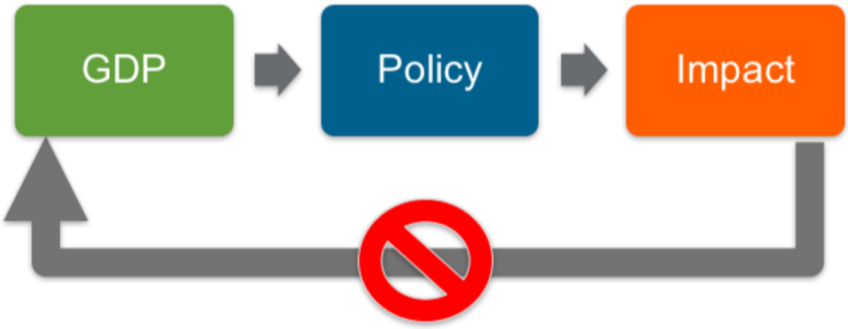

Figure 1: The Difficult Relation between GDP, Policy and Impact.

There are several reasons why GDP could fail to capture those changes (Costanza et al., 2009). Kuznet has always been very clear about the limitations of the GDP as a measurement of welfare, but after the Bretton Woods conference in 1944 GDP became the main instrument to measure not only countries' economies but also the main performance indicators to be used for all welfare, innovation and overall policy measurement and development.

Although there are several issues in the correlation of GDP and welfare well-known in the economic literature, this study focuses on measurements that are invisible to GDP but increasingly important because of the digitalisation of society. In particular, the impacts of knowledge and data affect the soundness of GDP as a comprehensive measure to monitor and assess the wealth of nations. GDP is not invalid, but becomes less helpful because the data economy is more fluid and many factors are not measured in conventional accounting methods.

1.2.2. Critiques

From this perspective, there are five principal criticisms of GDP.

The first criticism is connected with accounting of household activity, which is very important in today's "gig economy"[4]. As Ahmad and Koh (2011) said in their note for an OECD report, GDP as defined in the System of National Accounts (SNA) of the United Nations (UN) does not consider activity produced by "households" for own consumption as part of GDP. Generalising, the activities done by unpaid workers, riders, interns or free overtime are unmeasured in GDP. The Office for National Statistics in the UK (ONS, 2016a) estimates that unpaid work in a well-developed economy like the UK has a weight of at least 56% of the GDP.

[4] Task based employment. See https://www.macmillandictionary.com/buzzword/entries/gig-economy.html

A second criticism comes from the calculation of financial activities as a positive contributor to GDP. Banking and finance in general were excluded for a long time (1968) from GDP calculation. Only in 1993 was the measurement method for banking and finance fully defined and implemented. Assa explained that the way those measurements are taken relies on statistical indicators from various intermediate sources who combine identities, accounting rules, pieces of economic theory and assumptions related to factors that are not clearly measured. The primary inputs are transformed to arrive at the final estimates (Assa, 2015). The work of intermediaries, is increasing greatly, and could increase the "errors" in GDP computation since they build in assumptions regarding each measurement and index. The measures also do not explain the relationships and dynamics among the ecosystem's players.

A third criticism relevant for our study, relates to the depreciation of assets and natural capital. The first part of this criticism is mostly technical and connected with the correct depreciation method used by different countries and the depreciation of new economy related artefacts or "products", if they are even measured or registered as assets (Open Source as an example is not included). Diewert and Fox considered not only that depreciation is little considered in GDP but also that net output calculator should be considered since cross country comparisons are complicated by different methodologies for accounting (Diewert and Fox, 2005). Net measure can easily address the problem of increasing proportion of investment of knowledge economy artefacts requiring very fast depreciation.

A fourth criticism is related to the concept of natural capital, the inability of GDP to measure quality of life (Costanza et al., 2009) and if and how to measure natural capital. In this context, GDP can be seen to support opportunistic short-term behaviors that favour short-term depletion of resources against long-term community well-being. Fioramonti (2013) stated that GDP *"gives mankind the illusion that growth is about production, when it actually should be viewed as transfer … By definition, infinite growth on a planet of finite resources is incompatible with global justice, at least in so far as it triggers a dangerous zero-sum game"*. The way to measure the contribution of natural capital to GDP with environmental indicators has been discussed by several economists (Stiglitz e*t al.*, 2009; Coyle and Mitra-Kahn, 2017), who suggest alternative measures. Costanza *et al.* made several estimates about ecosystem services (Costanza, et al., 1997). In 2005, the UN created a project to value those ecosystem services, but many economists believed that giving a value to natural resources could even be a trigger to new opportunistic behaviour (Kallis, et al., 2013) since it could create a market for natural capital (Monbiot, 2012). This is still an open dilemma that cannot be easily resolved.

A fifth criticism is that GDP is incapable of measuring investment and productivity especially related to knowledge artefacts. As previously mentioned, this study relies on the fact that standard measures of the economy like the Gross Domestic Product (GDP) are not good enough to provide an accurate assessment of policy impact and not enough to offer a good starting point for the identification and mapping of new policy objectives. This is particularly true for digital technologies and intellectual products that are challenging the overall system because the economy relies to a lesser and lesser extent on material goods (Coyle, 2015).

This does not mean that GDP is invalid, but it is less helpful because the data economy is more fluid, networked and not measured correctly by conventional accounting principles.

Coyle explains very clearly, why GDP is not able to correlate growth and emerging trends in digital technologies (Coyle, 2017). The GDP is aggregated vertically from individual transactions. However knowledge production, software and collaborations in cyberspace are more transnational, cross-sectoral and multi-dimensional, totally different from the way the GDP has been designed to understand the Fordist mass industrial production. In her analysis, Coyle suggests three main reasons why GDP is not able to measure the non-material economy and why GDP struggles to measure these productivity gains:

- **Unpaid Services**: GDP is not able to measure the so-called digital economy and gig economy, where the growth of digital activities is driven by households and unemployed people doing activities that are not taken into account in the computation of GDP. Those unpaid services and volunteer-based digital production, such as writing open source software and Wikipedia pages, are not included and measured. Since the business models of platform companies are based on the concept of letting others do their work for them, this trend is extremely relevant in the networked economy. For example, Facebook does not produce content, the users do it for them, but Facebook obtains advertising revenues because of the content contributions.
- **Business model variance**: Business models for digital services differ greatly from the industrial world. For instance: i) the Android platform is given for free in order to receive data to be processed by Google for profiling purposes; ii) free services are financed by advertising; iii) cross-border crypto trading; and iv) cross-border supply chains. All those business model implementations have a direct impact on GDP.
- **Quality of service**: Coyle argues that the quality of service and increased productivity and choice in on-line distribution models is not adequately measured in prices. The potential explanation for this has to be considered in the pricing models that

companies use and in the network effect that they would like to achieve over time. For example, the pricing by Netflix is quite different from renting a movie at Blockbuster during the '90s. Netflix is considering an approach that is called lifetime value for the calculation of its revenues. Basically, they divide the real price of the service over a minimum number of months (the lifetime of the subscription) with the objective of acquiring as many customers as possible, to use their network to expand and to lock customers into a better user experience and distribution model.

This opinion is shared by many, e.g., Brynjolfsson and Collins (2019)[5]:

"*Digital media consumes a large and growing share of our waking lives, but these goods and services go largely uncounted in official measures of economic activity such as GDP and productivity (which is simply GDP per hour worked). We listen to more and better music, navigate with ease, communicate with coworkers and friends in a rich variety of ways, and enjoy myriad other benefits we could not have imagined 40 years ago. However, if you were to look only at GDP numbers, you would think that the digital revolution never happened.* ***The contribution of the information sector as a share of total GDP has barely budged since the 1980s, hovering between 4% and 5% annually and reaching a high of only 5.5% in 2018. To paraphrase the economist Robert Solow, we see the digital age everywhere except in the GDP statistics.*** *The reason the value of digital offerings is underrepresented is that GDP considers what people pay for goods and services. With few exceptions, if something has a price of zero, then it contributes zero to GDP."*

On the contrary, a study conducted by OECD (OECD 2017/09) affirmed that any potential measurement could not explain the reduced growth and economic slowdown in Western countries. Ahmad and Ribarsky go further by saying that most of the digital economy is already captured by current accounting frameworks, but is not correctly reported since accountants are not classifying financial data based on their business and distribution model (Ahmad & Ribarsky, 2018). The way today's accounting is done gives very little possibility to account for (the correct value of) intangibles.

With respect to the large number of digital businesses that just digitise offline businesses (for instance, a retail store and digital marketplace), permitting them to offer products or services more efficiently to a wider geographic audience, we would tend to agree with Ahmad and Ribarsky. However, those business models that capitalise on intangible assets or leverage consumer assets are much more difficult to analyse. For example, for Wikipedia and Open Source Software it is quite difficult to measure the real assets' value and contribution to GDP. Free services are excluded by GDP since they have no price. It is difficult to understand them with the current accounting framework, and their contribution to GDP (welfare gain) during their creation, usage and embodiment in derived products and services.

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[5] https://hbr.org/2019/11/how-should-we-measure-the-digital-economy

At the same time, Ahmad and Ribarsky (2018) confirm that in GDP the demand structure is particularly stable (demand for a particular good or service) and it does not consider the changes in the market structure; for GDP the type of platform on which the product/service is consumed is irrelevant. See, for example, the transformation of the music industry by new platform delivery models including iTunes and Spotify, or the Open Source distribution of a product such as mobile software apps on Android. Therefore, it is very difficult to understand the reasons for the growth or decline of a specific industry. We agree with the authors recommending for a better classification of transactions based on a correct classification of the digital economy (Figure 2).

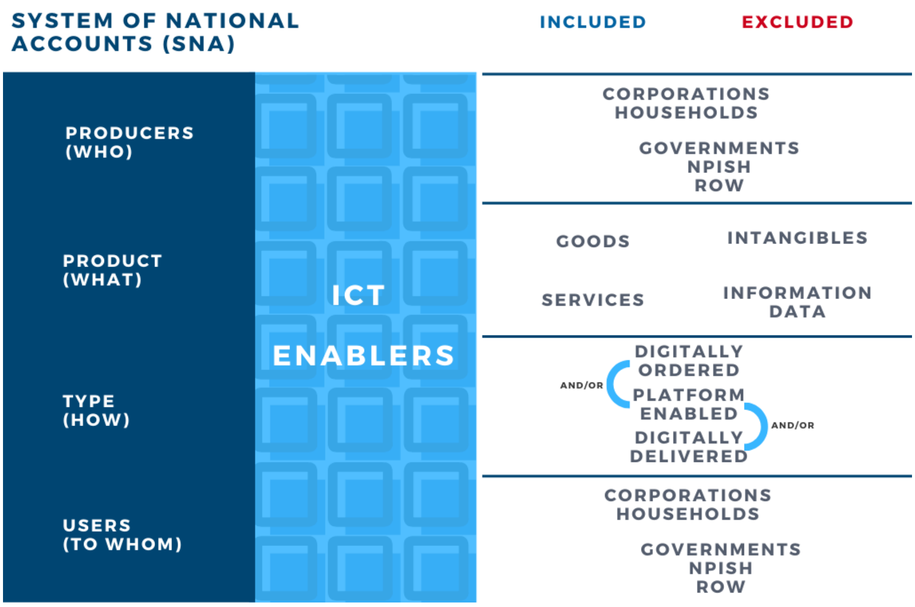

Figure 2: Dimensions of the digital economy and impact on SNA.

Brynjolfsson, et al. claim to demonstrate that platforms like Facebook generate a larger consumer surplus (measured by the compensation asked for not using such a platform) that can be between three and ten times higher than the average revenue per user reported in their accounting system. They advocate complementing GDP with an array of measures including their GDP-B metric that captures the consumer surplus generated by the free digital goods and other non-market goods. Their GDP-B metric is still partial because is uses only online choice experiments and is not complemented by real time data, but nevertheless gives some sense of how to complement GDP data with additional indicators (Brynjolfsson, et al., 2019). The correct measuring of intangible is a key priority since, as the ECB states in a recent report, ***"Investment in intangible assets enables productivity gains"***[6] (Andersson and Saiz, 2018).

1.3. The Impact of the Data-Driven Economy in Society

1.3.1. The Role of Intangible Assets and Structures

The connection between the physical and digital world is getting increasingly strong. At the beginning of the IT revolution, contacts among digital and physical were limited and mostly confined to business-related activities or gaming. Now the real world is augmented by technologies that are constantly changing the way resources and assets are transformed, used and traded.

As explained in the previous section, the digitalisation of the economy is generating new knowledge, connections and digital artefacts that permeate the economy, and economic externalities are increasing (positive and negative) because of IT and the global scale of relationships. However, there has not been a major change in the fundamentals of the economic indicators.

In 1989, Karl-Erik Sveiby, inspired by McLuhan wrote the first book worldwide on the accounting of "intangible assets." (Sveiby 1989, 1998). The book defined and explained why assets are evolving because of the post-industrial knowledge economy towards intangible assets. Sveiby distinguished three types of intangible assets (Figure 3):

1. *Human capital* — **Individual Competence** — the human dimension and knowledge of personnel. It is implicit and become explicit when shared among the organization.
2. *Structural capital* — **Internal Structure** — the assets and resources that the organization deploys to be used and upgraded by the personnel, including intangibles such as patents, databases, and the like.
3. *External capital* — **External Structure** — the external structures and relations of the company, its network, partners, networks of suppliers, users and clients. The network of resources and relationships needed to achieve success cemented by a high level of trust and reputation among the components of the network.

In his paper, Sveiby explained why he considered financial indicators (revenue, profit) as lag indicators and emphasised the importance of intangible flow as the only lead indicators for all organisations that are heavily dependent on knowledge workers. He described

[6] https://www.ecb.europa.eu/pub/economic-bulletin/focus/2018/html/ecb.ebbox201807_03.en.html

"Humans" as the only true agents of value creation. Under those assumptions, he defined the concept of the Intangible Asset Balance Sheet and the Intangible Asset Monitoring system to give visibility and facilitate the monitoring of the three indicators described above. The system he created can therefore explain the revenues/value divergence present in most of today's consulting and digital economy companies, because the evaluation of their market potential is mostly connected with the capability to attract (stock) and nurture (flow) those Intangible Assets.

Thanks to Sveiby's work, it is possible to say that those three key intangible assets (or stocks) are very relevant in current business and digital networks and refer to specific dimensions that explain contracts ecosystems following the STI approach. In particular, we see:

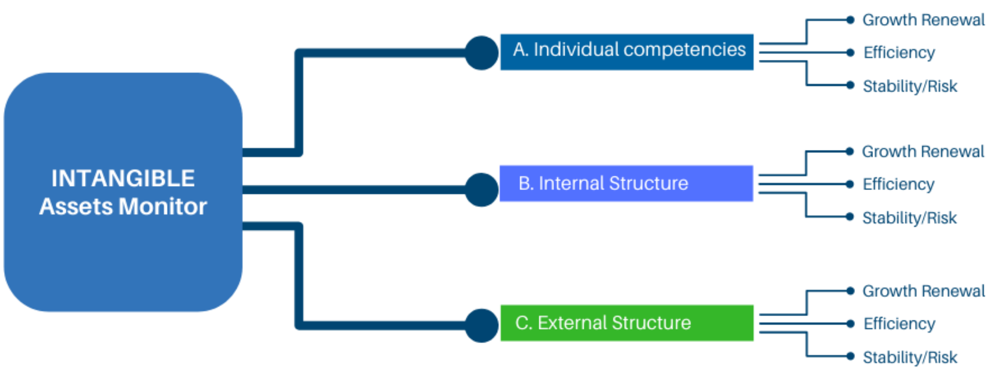

Figure 3: Monitoring Intangible Assets.

1. **Individual Competence -** is the culture coming from personnel and embedded in the way they share and enrich knowledge among each other;
2. **Internal Structure -** represented by the internal structure and the protocols and data, they generate and share using the technology to speed up the operations and sharing of knowledge;
3. **External Structure -** represented by the ecosystem they put in place to nurture, relationships, alliances and the digital platforms they enable to empower and magnify those links.

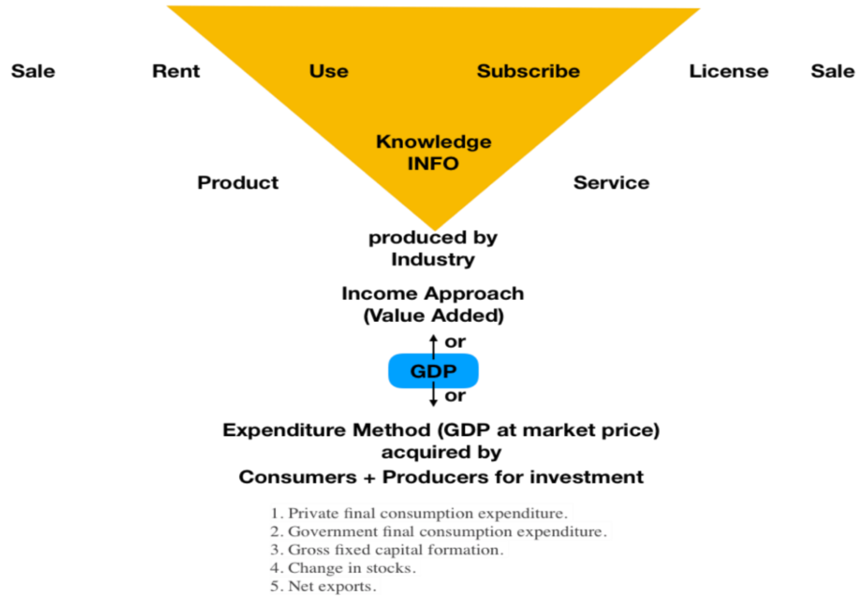

Figure 4: Contribution of intangibles on (Value Added) GDP.

Verna Allee, stresses that the model is not static (Allee, 2003). There is a knowledge and value flow between those three categories of intangible assets: "A company increases and utilizes its intangible assets by creating, sharing and leveraging knowledge to create economic value and enhance economic performance**.**"

Knowledge is created by sharing and the more it is shared, the more there is. Therefore, a system that facilitates sharing and leveraging external and internal contributions amplifies the possibility for success. This is different than "classical" views of "industrial" economists. The value-creation process differs from the industrial age since the production of knowledge artefacts are quite different; the value creation is not embedded in a tangible object, but is part of the knowledge creation process and the possibility to share this information or by-products in a free or paid form (Figure 4).

1.3.2. The Special Role of Open Source

The impact of intangibles in enormous. A leading example is Open Source Software. The Open Source movement[7] contributed to the acceleration of technology development globally. Open Source is essentially the scientific method applied to software. Like the scientific method, which transformed the knowledge economy of Europe beginning in the 16th Century, Open Source requires that the proponent publish in a format that can be understood, reproduced and extended. In science, this meant publishing methods and data. In software, it means publishing “code” in a format that is easily reused, and absence of legal

[7] The “open source” label was created at a strategy session held on February 3rd, 1998 in Palo Alto, California, shortly after the announcement of the release of the Netscape source code. https://opensource.org/history

restrictions. Reusable code, facilitates knowledge spillovers (Parker et al., 2016). The parallel with rights as data under the GDPR is striking.

Open Source refers to two things, an "open" legal regime, and a "source" format. In software development, there was a long tradition of organising code into "source" format - modules. The latter innovation was to use the legal principle of copyright to lock the code open, preventing it from being extended and commercially re-appropriated.[8] When in 1998, Netscape sourced part of its code favouring the spinoff of Mozilla, the battle between open and closed software was joined. Open Source has had a long battle with proprietary models, just as science has a long battle with alchemy and magic. But the logic of sharing is clear and the network benefits are ultimately overwhelming. In fact, we are currently seeing convergence on open methods.

Europe has led in many fields of open software, most notably the effort of a Finnish college student, Linus Torvalds[9], with Linux[10] which is now the operating system of most of the internet, including much of mobile. Torvalds also invented "git," which has become the principal tool for software collaboration. The special role of Open Source and the simple economics are well identified (Lerner & Tirole, 2005) and have been acknowledged and reflected in the new EC Directive excepting Open Source contributions from applicability.

This is the text from the Directive: *"(32) Free and open source software, where the source code is openly shared and users can freely access, use, modify and redistribute the software or modified versions thereof, can contribute to research and innovation in the market for digital content and digital services. In order to avoid imposing obstacles to such market developments, this Directive should also not apply to free and open source software, provided that it is not supplied in exchange for a price and that the consumer's personal data are exclusively used for improving the security, compatibility or interoperability of the software."*[11]

Companies are becoming more oriented to master intangibles and to use them as a growth factor. The possibility to virtualise business ecosystems online, access real time data and to facilitate new distribution models is dramatically changing the way the economy works. This is impacts the way that economic performance is measured, since GDP is not capable of measuring intangible assets and the three types of stocks defined by Sveiby. New business models such as SaaS platforms, new apps offered by gig-economy players, the

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[8] The use of "copyleft," copyright to lock software open, is credited to Richard Stallman and the GNU project. https://en.wikipedia.org/wiki/Copyleft.
[9] https://en.wikipedia.org/wiki/Linus_Torvalds
[10] https://www.linuxfoundation.org/#
[11] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=OJ:L:2019:136:FULL&from=EN

servification of traditional industries, like Airbnb, are heavily leveraged on intangibles and are dramatically changing market structures.

Because of the increasing inconsistencies and the overall stagnation of the economy, the United Nations System of National Accounts (SNA 2008, European Commission et al., 2009) has been revised to partially cover some of those gaps. In particular, the SNA was updated in 2008 as revision of the SNA 1993, then adopted in Europe with the ESA 2010 which is enforced for all EU Member States through EU regulation (EC) No. 549/2013, to include in the calculation the treatment of Research and Development (R&D) expenses as investment and other measures and corrections, to make the GDP better suited for today's economies.

Unfortunately, as Schreyer and Zinni (2018) identify, this does not solve the problem. Shreyer et al. explain that the instability of R&D asset values is affected by sunk costs, upfront investments and network externalities that are very difficult to measure. That means that aggregate returns to scale may not be constant but instead increase over time, since there are several spillovers generated by the same assets in a dense research ecosystem (Schreyer & Zinni, 2018). The other point they make is that R&D is not just an input value, but is a technology index whose stock pool affects the production forward, contributing to the success of a specific ecosystem. It is therefore an enabler rather than just an input factor (Diewert & Huang, 2011).

An additional aspect to be considered is the absence of any investment indirectly correlated with R&D that is reflected in the soft knowledge exchanged between like-minded people. In this situation, it is very difficult to correctly account the real value of R&D assets, because the way those assets are built is very hard to compute and market prices very hard to get. Therefore, later R&D and intangibles are accounted at cost, mostly wages of personnel directly involved in the R&D activities, without considering the other dimensions Sveiby described and the networks and data that today are available because of the digitalisation of society. Furthermore, the difficulty of determining the rate of depreciation and easy transferability, even across borders, affects R&D. This can generate infra-annual movements that could be difficult to capture while measuring GDP. Similarly, other intangibles are not part of R&D inputs and not even part of the revenues generated by companies (eg via advertising) as correctly explained by Brynjolfsson and Collis (2019).

1.4. Accounting Principles

The International Accounting Standards ("IAS") have been issued by an association of Professional Accountants (International Accounting Standards Committee ("IASC")) since 1973. This was the first attempt to standardize accounting rules worldwide. IAS 1 prescribes that the financial statements of companies based on IAS, must give information to a plurality of users, on the balance sheet, on the economic results and on the changes in the financial structure of the company.

To calculate the company's performance, the IAS require the production of a cash flow statement to evaluate the company's ability to produce financial flows. But that is static information, based on past accounting data, such as

a) revenue from the sale of goods and services;
b) revenue from royalties, fees, commissions and other payments;
c) payments of goods and services;
d) payments to employees; and
e) payments of income taxes.

Therefore, from the financial statement it is not possible to obtain information on the real economic value of the company, and on its ability to produce future income from the knowledge produced within the company, from relationships with other entities, from investments in human capital, and from the quantity and quality of data in possession.

As an example, years ago, when data was not automatically accessible, it was easy to make large mistakes as demonstrated in the case of AT&T, explained by a blog post by Professor Angel Lozano:

"In 1980, McKinsey & Company was commissioned by AT&T (Bell Labs invented cellular telephony) to forecast cell phone penetration in the U.S. by 2000. The consultant's prediction, 900,000 subscribers, was less than 1% of the actual figure, 109 Million. Based on this legendary mistake, AT&T decided there was not much future for these toys. Ten years later later, to rejoin the cellular market, AT&T had to acquire McCaw Cellular for $12.6 Billion. By 2011, the number of users worldwide had surpassed 5 Billion and cellular communication had become an unprecedented technological revolution." [12]

This is because IAS do not support the measurement of intangibles, while in the digital world many companies are light in physical assets but extremely profitable; the gap between market value and value of assets can diverge massively. When Facebook went public in 2011, the value of its total assets reported were US $6.3 billion, but its market valuation

[12] http://digital-stats.blogspot.com/2014/07/mckinsey-company-projected-that-there.html

reached as high as US $104 billion.[13] The huge gap between the two numbers implies the enormous value of its intangible assets, including the value of data. The value of data generated by Facebook users and the data analytics processes run by the company for advertising purposes generated in 2017 US $39.9 billion in advertising revenues, contributing to 40% of its annual sales growth (Forbes, 2017[14]). IAS 38 "Intangible Assets" outlines the accounting requirements for intangible assets. IAS 38 recognises an intangible asset if, and only if, certain criteria are met. IAS 38 also specifies how to measure the amount to be recorded of intangible assets.

1.4.1. Key Definitions

Intangible asset: an identifiable non-monetary asset without physical substance. An asset is a resource that is controlled by the entity as a result of past events (for example, purchase or self-creation) and from which future economic benefits are expected (IAS 38.8).

1.4.2. Recognition criteria

IAS 38 recognises an intangible asset, if purchased or self-created if, and only if: (IAS 38.21)

- it is probable that the future economic benefits will flow to the entity;
- the cost of the asset can be measured reliably.

If an intangible asset does not meet both the definition and the criteria for recognition as an intangible asset, the cost must be recognised as an expense when it is incurred (IAS 38.68).

Therefore, the following costs must be accounted to "profit and loss"

- research costs;
- formation expenses;
- costs incurred before the opening of a new establishment (such as start-up costs incurred before the plants produce at full capacity);
- expenses for staff training;
- advertising costs;
- costs related to software maintenance;
- restructuring costs and costs incurred for the reorganization of the business or of a production line.

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[13] https://www.sec.gov/Archives/edgar/data/1326801/000132680113000003/fb-12312012x10k.htm
[14]https://www.forbes.com/sites/greatspeculations/2017/10/30/facebooks-strong-ad-revenue-growth-to-continue/#b5f4d4a6fe78

The three main features of an intangible asset are:

- identifiability;
- control (power to obtain benefits from the asset);
- future economic benefits (such as revenues or reduced future costs);

Identifiability: an intangible asset is identifiable when it is separable to be sold, transferred, licensed, rented, or exchanged, or arises from contractual or other legal rights.

Control: The capacity of the entity of:

- taking advantage of the future economic benefits deriving from the intangible asset;
- limiting third-party access to these benefits (because of the presence of a legal protection on the activity).

Future economic benefits: May include:

- Revenues from the sale of products / services;
- Cost savings

1.4.3. Examples of intangible assets

Patented technology, computer software, databases and trade secrets trademarks, newspaper mastheads, internet video domains and audio-visual material (e.g. films, television programmes)

Intangibles can be acquired:

- by separate purchase
- by a government grant
- by exchange of assets
- by self-creation (internal generation)

Accounting treatment:

- Initial detection: Purchase cost + direct costs;
- Initial measurement;
- Next evaluation: fair value if an active market exists and if the revaluations are carried out with sufficient regularity for the whole category of goods.

Classification: There is no classification of intangible assets, but intangible assets are indicated separately in the balance sheet.

Therefore, the know-how produced within a company will never be reported on a company balance sheet. For this reason, the economic value of companies such as Uber or

Facebook is higher than the value of assets accounted for in the financial statements based on IAS, which reflect cost or fair value.

Following this approach, the divergence of value of intangible and assets accounting is transferred to the next levels where National Accounting Systems aggregate data based on those principles. As specified by other economists (Li et al., 2019), in most cases the value of data is generated when a firm has a data-driven business model. To measure intangibles, there need to be proxies in the Annual Income Statement to report the value of intangibles. To do that it would be necessary to add to the financial statements, a shared and updated ledger, which shows the real economic value of intangible assets and the real wealth produced by the ability to create value. In a shared and updated ledger, there could be the real value of the ecosystem in which to detect the wealth produced, and to detect any loss that this has on other traditional economies. This more inclusive ledger could measure the variation of unpaid services, the business model variance and the quality of service improvement advocated by Coyle (Coyle, 2017). This ledger could be linked to the organisational capital of the company and eventually to the sales, general, and administrative (SG&A) expense as advocated by Li (Li et al., 2019). It could also include the formalisation of a knowledge-based structure advocated by Sveiby (Sveiby, 1989, 1998).

A small example: Uber has no assets on the balance sheet, no taxis or employees, but has an economic value estimated at 17 billion dollars; on the other hand, the economy of taxis, as a transport system, has had a negative impact. Another example is the decline that travel agencies experienced with the advent of online booking. The updated shared ledger must record the economic growth in some sectors and the losses of traditional sectors. The ledger must always be updated because the scenarios change.

1.5. Understanding Intangibles Value via Contracts

It is now clear that in a world progressively dominated by digital platforms and ecosystems, the capability to correctly interpret and analyse large volumes of data is becoming critically important. Data-driven economies, the Internet of Things and other trends make vast amounts of data available. But the formats (syntax) and meanings (semantics) of the data varies needlessly, and much data is unstructured or semi-structured.

We believe contracts and in particular native digital contracts can establish a positive feedback loop of network benefits that will lead to harmonisation of syntax and semantics. The increased use of digital forms of contracting (or performing contracts even where the contract itself is not directly computable) creates a wealth of new relational and transaction data that can be used to model complementary views of the network of economic trades and relationships. The availability of large volumes of data and the possibility to monitor not only transactional but relational data in connection with digital contracts can offer an opportunity to develop complementary measure(s) to GDP that can capture real-time information to be used by economists, legal and regulatory institutions to define and model better policies. This will permit understanding value creation, and also the assets and intangible used as productive factors that are directly responsible for the incremental value of businesses and ecosystems.

Such views would not replace GDP, but provide additional views that complement GDP. In terms of basic units of accounting in a network or ecosystem of contracts view of the economy, monetary value would continue to be used. But the possibility to understand economic trends and societal changes is directly correlated with the capability to model, aggregate, process and analyse large volumes of data that are now available. The GDPR (Regulation (EU) 2016/679) and PSD2 (Directive (EU) 2015/2366) offer an opportunity to materialise and visualise such data networks. Those two directives encourage more transparency in relations and data treatment for business users (Regulation (EU) 2019/1150, Article 8.) Each of these laws require contractual expressions of rights, terms and conditions.

This vision can be realised by structuring transaction information and the contracts that define their meanings.[15] This can also encourage more secure data management. To the extent that information is structured and labelled, better conclusions can be derived from smaller quantities of data, enabling efficiency even with much less concentration in the ecosystem of data intermediaries. Structured information also permits a business or individual to better exercise their right to data portability under the GDPR, encouraging competition. A system of structured contract templates enables more efficient contracting by all participants, reducing the cost and ambiguity of contracting, enabling better reporting, increasing competition, reducing the needed size of the intermediaries and reducing systemic risk (Kavassalis et al. 2018). To better analyse and explore this opportunity we need to investigate the EU ecosystem as a complex adaptive system (see Ritala & Phillips, *in press*) of interconnected agents where contracts are connecting edges of a dynamic graph (Basole et al., 2015; Järvi & Kortelainen, 2017). The opportunity is to empower policy makers with realtime artificial sensing (Gross, 2017), to use "Smart Contracts" (Szabo, 1994) to implement the "report once" principle (Sel et al., 2017), and the human-AI decision systems (Pentland, 2019).

[15] Data Management Policies for GDPR Compliance at Run Time https://lirias.kuleuven.be/retrieve/520305

The need to move from analogue to digital indicators is evident (Still et al., 2012). Turning digital data traces into dependable insights that can support decision-making and policy-making is not trivial and can only happen with a strong and rigorous modelling exercise (for a popular exploration of the topic, see e.g., Silver, 2012). A system of expressing contracts via standard templates can have benefits at a micro-use level that expand via network benefits into a general dynamic of structure and standards.

2. TECHNOLOGY REVIEW - FEATURES AND IMPACT OF INTERNET AND THE INTANGIBLE SOCIETY[16]

2.1. Introduction

The Internet represents a massive shift in the way that information is sourced, exchanged and used. It also demonstrates the process of standards-based open development replacing closed solutions in successive waves. The Internet was originally based on the existing telecommunications infrastructure of telephony, which was dominated by highly regulated monopolies that were loosely networked via standards, agreements and regulations. This regulated monopoly structure was transformed by new entrants empowered by Internet technologies, notably Transmission Control Protocol/Internet Protocol or TCP/IP, a minimum viable datagram and exchange standard. The new entrants rode on top of the existing structure and created parallel infrastructure. They developed ecosystems of participants, intermediaries, software and hardware developers that expanded into all aspects of communication, eventually threatening even the original monopolies.

The first general system of collaboration was email, which permitted any person to communicate with any other person, without regard to their computer system, location or software stack. This was complemented by shared publishing - the World Wide Web (WWW) based on the HyperText Transfer Protocol (HTTP) and Hypertext Markup Language (HTML). These “open” approaches competed with closed approaches and with other standards for some period, but the network benefits for participants (the advantages of being part of a larger community) and the ability of participants to improve and extend the approach (decentralisation of development) caused TCP/IP, email and WWW to incorporate the others. A similar transition is now taking place in contracting.

In this chapter, we explore:

1. The key features and concepts and aspects of the Internet-based and data-driven economy.
2. The role of digital ecosystem players that are re-centralising assets (tangible and intangible), production inversion and subsidising services.
3. The concepts behind blockchain and smart contract uptake.

[16] This chapter was written by Luigi Telesca with contributions from James Hazard, Mahfuzul Islam, and Ali Hassan.

2.2. How Telecommunication Infrastructure and Internet have Changed Transacting

With the advent of telegraphy and radio transmissions in the early 19th Century and then the penetration of wirelines, mobile telephony and finally the Internet, technology gave a massive innovation impulse to our societies, facilitating growth and economic development around the globe. As the first industrial revolution transformed production methods and increased GDP, the same has been done by telecommunications for labour productivity, in the formation of national markets and increasing velocity of international trade.

To reach such an advanced state of development, many innovations had to be created and adopted. Much of this occurred as a result of private efforts, many of them in proprietary, local, walled gardens. But in a globalising economy, as the systems scaled, interoperability became increasingly essential. A big coordination effort among national governments and standardisation bodies had to take place to facilitate seamless transport of analogue and digital packets across different regulatory regimes and legislations. The International Telecommunication Union (ITU) (ITU, 2019), a specialised agency of the United Nations, played a pivotal role in the harmonisation and diffusion of global standardisation activities across the globe, with the support of all governments. ITU is globally responsible for coordination of global radio spectrum use, promotion of cooperation on communication activities and coordination and development of global technical standards in the telecommunication space.

2.2.1. The Origins of the Networked Economy

ITU was formally created in 1932 as the merger of the International Telegraph Union and the International Radiotelegraph Union, both of them responsible for important results in the harmonisation of their respective technological domains. In particular, the respective entities were the result of the International Telegraph Convention ("The 1865 International Telegraph Conference" ITU, 2019) signed by more than twenty European Governments that agreed to implement basic principles for international telegraphy, and the listing of radio regulations created and signed by 29 nations at the International Radiotelegraph Convention ("1906 Radio Conferences," 2019) in Berlin with 29 states attending. Having a unique standards-based communication infrastructure was a foundation for all future innovation and the creation of a global standardised market. The European states saw a need for more extensive agreements and regulations among them. This took the form of multiple bilateral agreements among them. The structure was backed by national regulations and national telecom operators that were responsible for the infrastructure development and international interconnection.

2.2.2. Telecommunication Networks and GDP Impact

Network interconnection is a very important topic that has been widely discussed and regulated by ITU. Simultaneously, a large number of international organisations are responsible for ancillary aspects relating to their core interests. In this respect, the World Trade Organisation ("WTO") actively contributed to telecom regulation as a means of promoting statutory objectives and the facilitation of international trade. For WTO, the interconnection among national markets is a central topic; since telecom networks are the vehicle for communicating trade data, the WTO has a special interest in the regulation and post-consolidation deregulation of specific markets. The WTO defined interconnection as the: "Linking with suppliers providing public telecommunications transport networks or services in order to allow the users of one supplier to communicate with users of another supplier and to access services provided by another supplier, where specific commitments are undertaken." (Intven, 2000). As we can see from the definition, initial attention of policy makers and regulators has been focused on technical specifications, deployment support and policy support for network development.

A unified, level playfield was mandatory, therefore national players worked together to facilitate the interconnection of networks and supported the definition of interoperable protocols at network core level to avoid the creation of lock-in effects from hardware providers. At the same time, government regulation was motivated by the high risk of anti-competitive behaviour in telecommunications: companies can reach end-users only through the networks of their competitors and therefore competitors must compete and cooperate at the same time.

Regulation was cumbersome for all the operators and governments, but the effort was not fundamentally impeded by anticompetitive behaviour of the operators since the interconnection of networks operating in different geographic regions was a good investment for the operators themselves, who enjoyed national monopolies. The need for more regulatory pressure came later to favour competition even at the intra-national level. As explained in the several economic studies starting from the 1980s, there is a positive connection between the penetration of wired and wireless networks and the impact on economic growth, unemployment and productivity (Hardy, 1980; Karner and Onyeji, 2007; Jensen, 2007; Katz et al., 2010; Katz, 2011; Katz et al., 2012a; Katz et al, 2012b, Arvin and Pradhan, 2014). The

ITU (ITU, 2012) also graphically explained the relation between Broadband penetration and GDP impact through four types of effects (Figure 5).

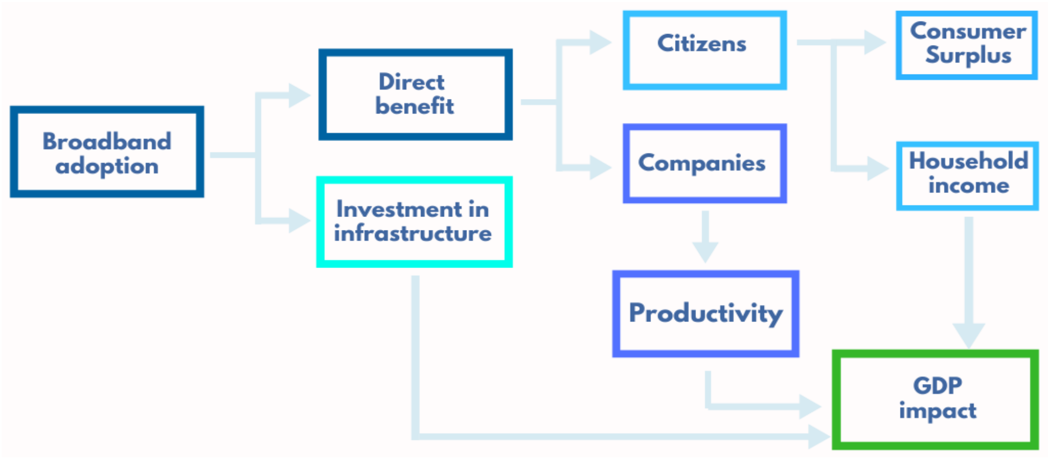

Figure 5: ICT and Broadband economic impact (on GDP).

In a recent study (ITU, 2018), the ITU also offered additional evidence based on econometric modelling that demonstrated that investing in networks and network capacity can increase the GDP of a country. In particular, a 1% increase in investment on wireless network can lead to an increase of .15% of the GDP while an increase of 1% of the fixed broadband network can contribute to 0.08% in GDP growth (Figure 6).

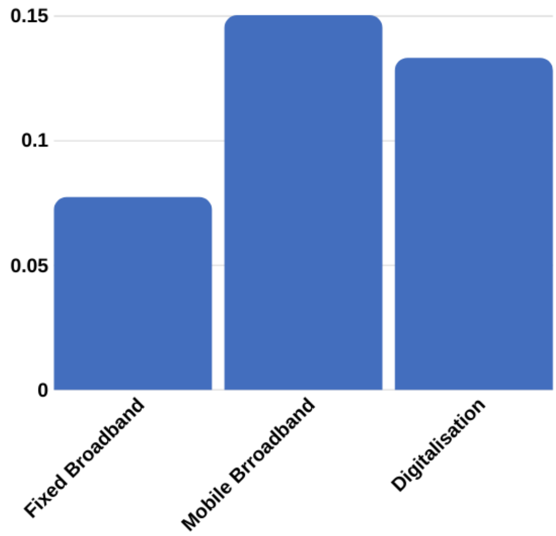

Figure 6: Impact on GDP of 1% increase in independent variable (data from ITU, 2018)

2.2.3. Economies of Scale and Network Effects

Most of the decisions taken in the telecommunications space were affected by the opportunity to find network effects, a term introduced into economics by Rohlfs (Rohlfs, 1974). Many other authors contributed to the enrichment of this concept (Shapiro & Katz, 1994; Rohlfs, 2003; Shapiro & Varian, 1998) each of them offering a better understanding of the economies of interconnections among networks. The core economic concept is that the users of a network obtain benefit from network effects if an additional user consuming a good or service on a network benefits from the other users already participating in the network (Varian, 2017). Reciprocally, the new users benefit the existing users as well as themselves. This is effectively depicted in the graph (Figure **7**), in which we can see three equilibrium points. A zero equilibrium with no users adopting the technology (i), an intermediate equilibrium with few users adopting the technology (ii), and an equilibrium when a large number of users adopt (iii). The first and third equilibria are perfect states while the second equilibrium tells us that a limited number of users are not sustainable over a long run; the technology or network in the second equilibrium could disappear if it does not attract more users. The willingness of users to pay gets higher is more users are added. The middle equilibrium point is a fragile state, also known as the critical mass; the minimum amount of adoption needed to make the network sustainable, but critical mass does not assure the network's survival over the long run if it fails to scale to higher numbers.

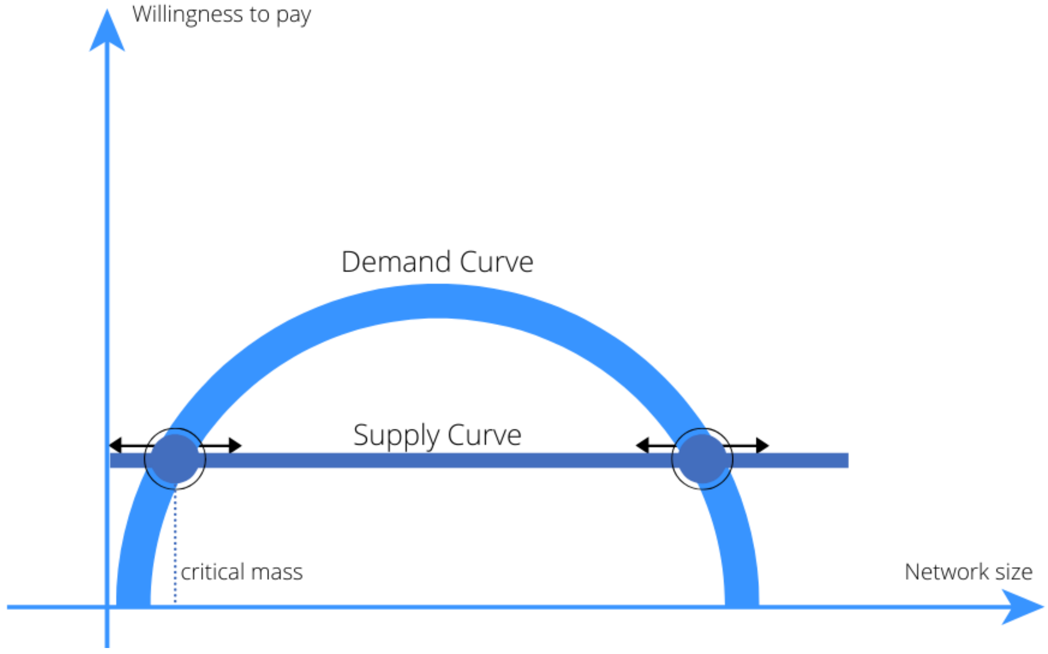

Figure 7: Network equilibrium.

Interconnecting networks is important because it can support both **supply side economies of scale** and **demand side economies of scale**:

1. **Supply Side** (economies of scale)
   - The average cost of creating a new output is smaller at a larger level of outputs. This is true for manufacturing physical items (*e.g.*, cars) and much more so for digital services and products which often have high costs of development and nearly zero cost of replication.
2. **Demand Side** (economies of scale)
   - The value of adopting a new offer for a new user is larger if others have already adopted the offer. This is often very strong for digital services or products where users are sometimes even willing to take part in the production or diffusion of the offer in order to increase their own perceived value.

Telecom players were initially obliged to interconnect (Figure 8) in order to achieve critical mass and global coverage, enabling services that were not available without interconnection (*e.g.*, international calls), but the concept of interconnections changed with the advent of new technologies, market players and transport technologies.

2.2.3.1.Interconnection Types and Regulation

As previously explained, the interconnection of adjacent telecom networks to create an international system of state-owned operators was mostly fulfilled (Telecommunications Regulation Handbook 117, n.d.).

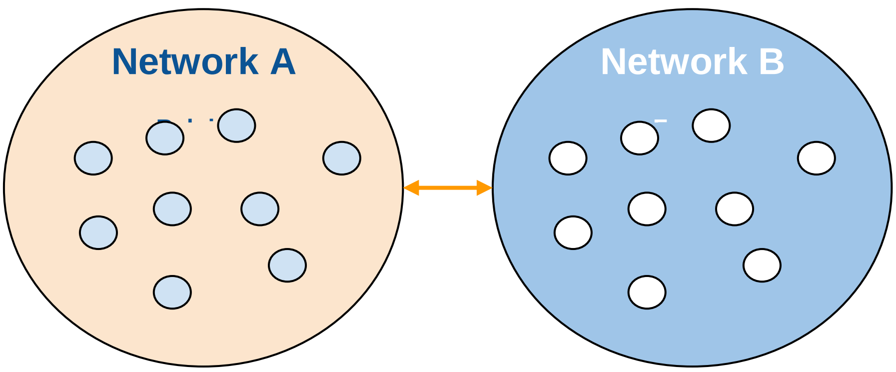

Figure 8: Interconnection of adjacent networks.

With the advent of wireless technologies and the penetration of mobile phones it became necessary to facilitate **interconnection among different types of communication technologies** (wireline and mobile). This happened both for incumbent wireless networks and for new competitors entering in the space. In order to obtain a licence to install and transmit wirelessly, all incumbent and new operators had to compete for a piece of the national spectrum that was made available by national governments. This opened up competition to new types of players and created the need for new types of interconnection (Figure 9).

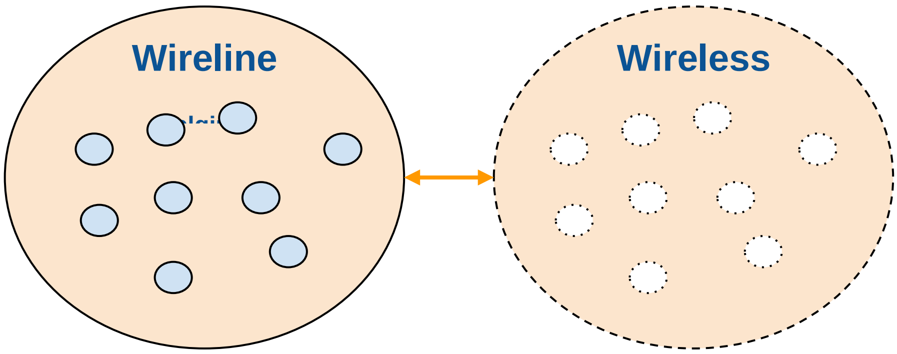

Figure 9: Interconnection among different types of communication technologies.

Network operators are currently running the fourth generation (4G) of communication technologies, characterized by the increased bandwidth available to the users for coping with ever-increasing data demands. Behind the new extended bandwidth features shown by the 4G Radio Access Network (RAN), operators require the deployment of a complex network able to feed each of the hundreds of points of access for users. This network, known generally as "backhaul," is responsible for connecting all the network access points and forwarding all the data consumed or generated by the users to the core of the network. In this way, the backhaul network expands from the last mile connection, reaching the point of attachment (e.g., NodeB or Small Cell) to the regional network, transporting the data to the core elements of the network. Depending on the deployment scenario and the locally available infrastructure, the backhaul network makes use of different technologies and deployment options. Typical state of the art backhaul networks include an amalgam of technologies such as point-to-point microwave links, fiber-optics or even copper links. Backhauling options for connecting cellular base stations to the core of the network are clearly led by fiber solutions, requiring expensive roll-out operations.

Another technology widely used is the point-to-point connection of base stations to aggregation points by means of microwave radio links. Another scenario currently very relevant is the deployment of Small Cells. The backhauling options range from direct connection to the core, taking advantage of Fiber to the Home or FFTH last-mile connections (typically serving fixed-access nodes) for the connection of the Small Cell, to any kind of wireless technology connecting to an aggregation point on the top of a building, from which a radio connection or a fiber is used to connect to the core.

To conclude this initial analysis of the current situation of backhaul networks, we should also consider the transport network in charge of carrying the aggregated traffic to the core network. This transport network has evolved through the years, being upgraded as the traffic demands exceed the capacity of the installed network. Due to this evolutionary nature of the transport network, it is typically comprised of a mix of different transport technologies and protocols, including legacy Asynchronous Transfer Mode (ATM) links, Multiprotocol Label Switching (MPLS) or even IP traffic over carrier-grade Ethernet technologies. Focusing on the evolution towards 5G, the new generation of networks will be characterized by a leap forward in RAN capacity and differentiated services. 5G networks will be designed in such a way that services with disparate requirements such as Internet of Things (IoT), Machine to Machine (M2M), video distribution or real time applications are transported over the same network, which will be able to adapt to these new service requirements and create a new wave of telecommunication services.

As wired and wireless network penetration and the number of users increased, new players sought to enter into the market. In order to recover the large investments done in copper and fiber, governments from many countries organised a wave of privatisation/deregulation in this space and networks have been unbundled to favour the entrance of new players (Figure 10).

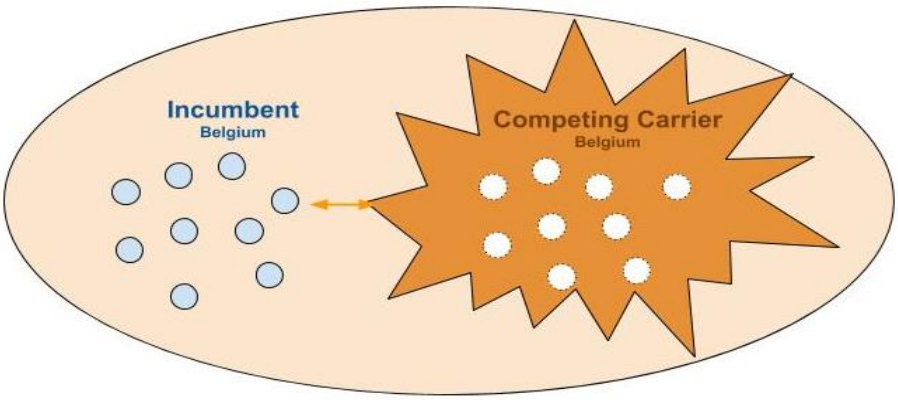

Figure 10: Interconnection among competing networks.

Network unbundling or Local Loop Unbundling ("EUR-Lex - l24108j- EUR-Lex," 2019) is a way for regulators to oblige incumbents to open up their core networks or to offer specific elements of their networks to other operators. There are two main approaches in unbundling:

a) The first one requires the new operator to install network elements (switches) at the incumbent central business districts and lease part of the incumbent network elements to serve other customers outside the districts.

b) The second option is for the new operator to lease network elements of the incumbent and offer its services at retail level (e.g *DSL, mobile services) avoiding network component duplication by reusing network capabilities already offered by the incumbent.

With the advent of the Internet and the expansion of Internet Service Providers, a new type of interconnection was required. Regulators had to facilitate **interconnection between Internet Service Providers and Incumbent Local Carrier Networks** to offer the possibility to use dial-up services for Internet connection (Figure 11). At the beginning, the competition was limited and the penetration of computers was negligible, so dial-up access did not create important threats to incumbents.

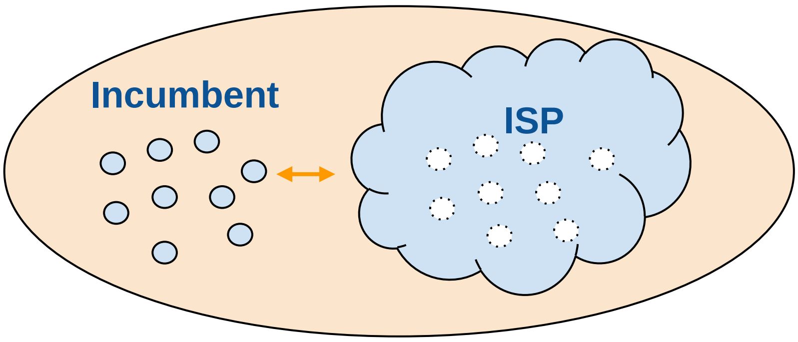

Figure 11: Interconnection among Local Carriers networks and Internet Service Providers.

2.3. The Race to the Top

Because of the disruptive nature of the Internet, new services began to emerge, including a new generation of players called Over-The-Top (OTT) since they were leveraging telecom investments and resources for free. OTT entrants began to compete directly with Telco operators for important revenue streams (e.g., Skype)[17]. OTTs are service providers that do not need to operate or lease network from telecom operators since they rely mainly on the Internet access network to provision their services.

[17] https://en.wikipedia.org/wiki/Telco-OTT

The operators started to feel the pressure since the Internet was benefitting from a deregulated environment and simplified technical structure that lowered barriers to entry for new market players.

For some time, the critical positioning of telecommunication networks was largely preserved; development mainly focused on extending network penetration and the introduction of wireless technologies. That increased the speed of communication in a sector where resources had always been regulated, with an assignment of exclusivity rights to operators in exchange for guaranteeing public access to resources. The Internet caused this to change; the intrinsic nature of the Internet's TCP/IP protocol (see below) allowed the creation of a backdoor into the telecom ecosystem (Figure 12).

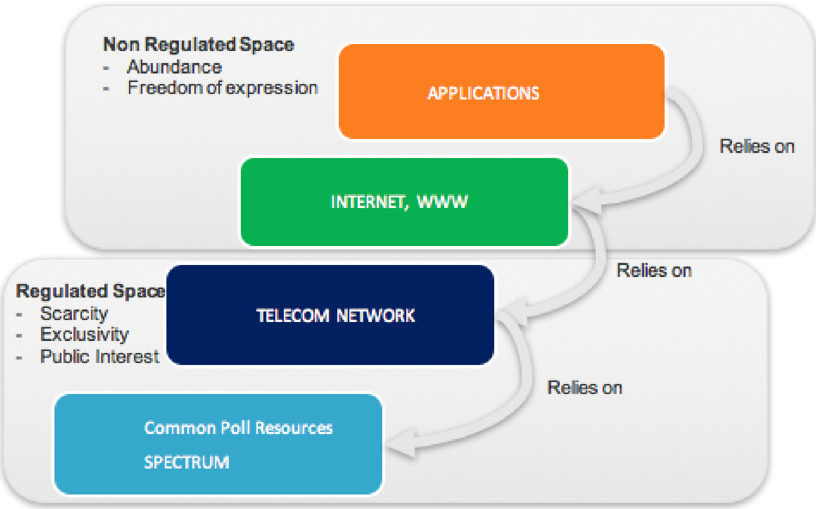

Figure 12: The Internet Ecosystem.

New service offerings were introduced that had high economies of scale, network effects and community-driven growth without the burdens and constraints of regulatory and administrative requirements that Telcos had to comply with.

In the USA, the Clinton administration defined the end of the telephone age and the beginning of the Internet age with the 1996 Act (Ehrlich, 2013) facilitating the spread of the Internet mostly via private investments. Among other things, the 1996 Act required the introduction of Digital Subscriber Line technology (DSL) by the end of the decade to favour future network convergence.

Similar progress happened in many developed countries, which took regulatory actions to favour market competition instead of network operator incumbents. In Table 1 provides some of the core differences between Telecom Operators and Over the Top Players.

Table 1: Telco, OTT differences

Telecom Operators	Over The Top Players
Geographically bounded	Non geographically bounded
-Universal Service	-No Scarcity
-Natural resources	-Computing is the limit
-Spectrum is the limit	-Moore's Law infinite?
-Economies of Scale	-Core density
-Increasing infrastructural costs	-Low scalable investments
-Limited growth	-Community driven
-High barriers to entry	-Economies of Scales
-Network neutrality	-High Growth
-Regulated pricing, SLA	
-Low Margins	

2.4. The Disruptive Nature of the Internet

The Internet can be said to have started with research on packet switching (Kleinrock, 1961)[18], the creation of the ARPANET (1966) and the invention of TCP/IP (Cerf, Kahn, 1973). These three innovations gave rise to the Internet, "*a world-wide broadcasting capability, a global channel for information dissemination and a medium for collaboration*" (Leiner et al., 2009). Internet and subsequently the World Wide Web (WWW) (CERN, Berners-Lee, 1989)[19] have been the spark to a global transformative effort that changed the way that people interact, consume, work and trade.

For the first time in history, a large part of the planet had access to a mesh of networked communication, an "inter-net," conceived not just for a particular kind of communication and limited set of applications, but for a global platform supporting an unlimited number of applications and data standards.

The key to the Internet's success is a major simplification, a minimum viable specification that allowed maximum flexibility and interoperability. The Internet Protocol (IP) supports all the upper layers by offering a method of delivery of datagram packets to a named

[18] https://www.lk.cs.ucla.edu/data/files/Kleinrock/Information%20Flow%20in%20Large%20Communication%20Nets.pdf
[19] https://www.w3.org/History/1989/proposal.html

address. The datagram packets have a minimum viable format requirement and are otherwise agnostic. The simplicity behind IP made it possible to easily interconnect and run over a wide range of link layers, enabling the rapid development and adoption of the Internet.

Internet Protocol and Transmission Control Protocol (TCP) (Leiner et al., 2009), initially conceived for researchers and the military, was simple and came to be used to support the proliferation of client-server infrastructures and the growth of personal computers. The need for interconnecting systems was evident. Scientists wanted to share very expensive equipment by accessing it from remote connections, using applications, data and information could be easily shared.

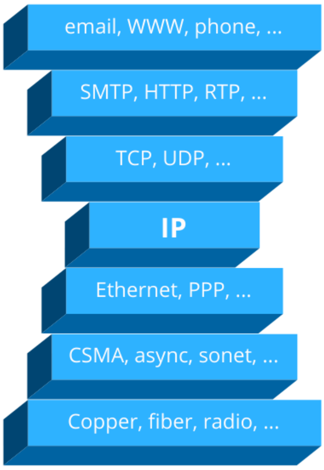

Figure 13: The Internet Stack.

In this context, the first major Internet application was created: email. Email, notwithstanding its limitations, was a common format and protocol for any person on the Internet to communicate with any other person on the net, using whatever application ("client") they preferred, with a decentralised data management via compatible servers. This permitted researchers to coordinate their efforts rapidly. Email facilitated knowledge sharing and coordination without physical presence.

However, it was the invention of HTML, HTTP and the World Wide Web (WWW)[20] that caused the Internet to explode. It, too, is simple in concept. It brought a standard way to present a text, and emphasised the linked nature of information.

[20] The first Browser from CERN https://worldwideweb.cern.ch/browser/#https://worldwideweb.cern.ch/browser/default.html

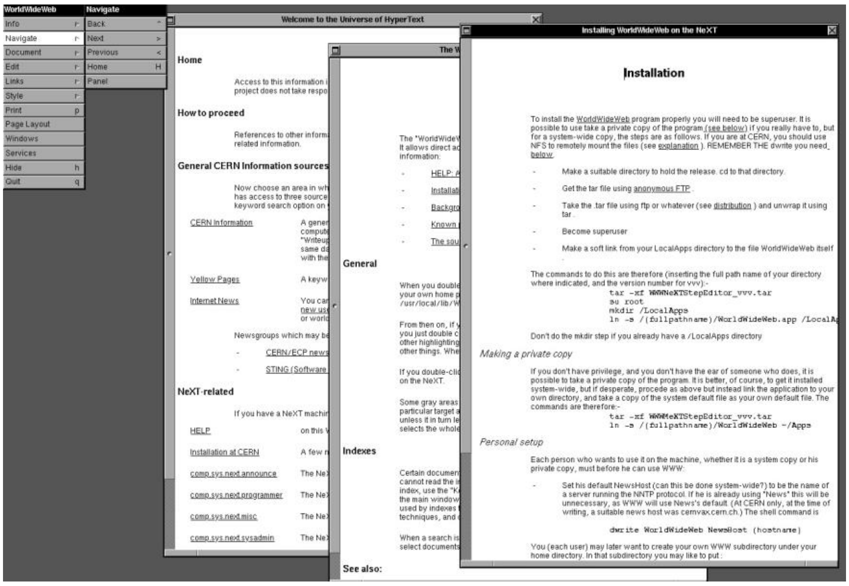

Figure 14: The Internet via the World Wide Web.

With the mass adoption of TCP/IP in personal computing, the increased computational power (Moore, 1965) and the possibility to resolve Internet addresses in a user-friendly way via browsers, use of the Internet exploded. As an open ecosystem, it marginalised proprietary networks such as Compuserve, AOL and Minitel.

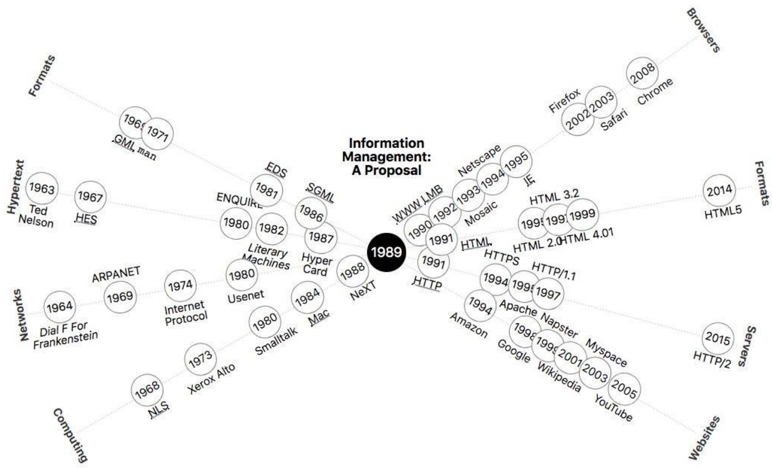

Figure 15: The dependencies and impact of the World Wide Web (CERN).[21]

At the beginning, information was mostly limited to static web pages and some expert user forums. The classification of knowledge was hierarchical. There was very little

[21] https://worldwideweb.cern.ch/timeline/ , coutesly https://copyright.web.cern.ch/

information about the content on the Internet, metadata of a higher layer, and therefore initially the idea to curate data using human classification was feasible. Yahoo developed a lead in this, and network benefits allowed it to start to ask for money to include commercial sites. The increasing amount of user-generated data made the categorisation exercise expensive. This led to web crawlers indexing large volumes of web pages and documents and the first search engines started to process natural language queries[22]. Unfortunately, the quality of results dropped since the model for indexing pages was poor. This problem was solved when it was recognised that the links among the materials provided critical information about the meaning and importance of the distributed information. By focusing on the links among websites, search engines become scalable. The founders of Google started working on BackRub, an early version of the famous search engine, which used these links to materials, the “backlinks,” to evaluate the importance of the material.[23] B ased on that insight, they created a scalable indexing mechanism, that leveraged users’ validation and classification of relevant content, crowd-sourcing curation. This has been the paradigm for the success of search until the present.

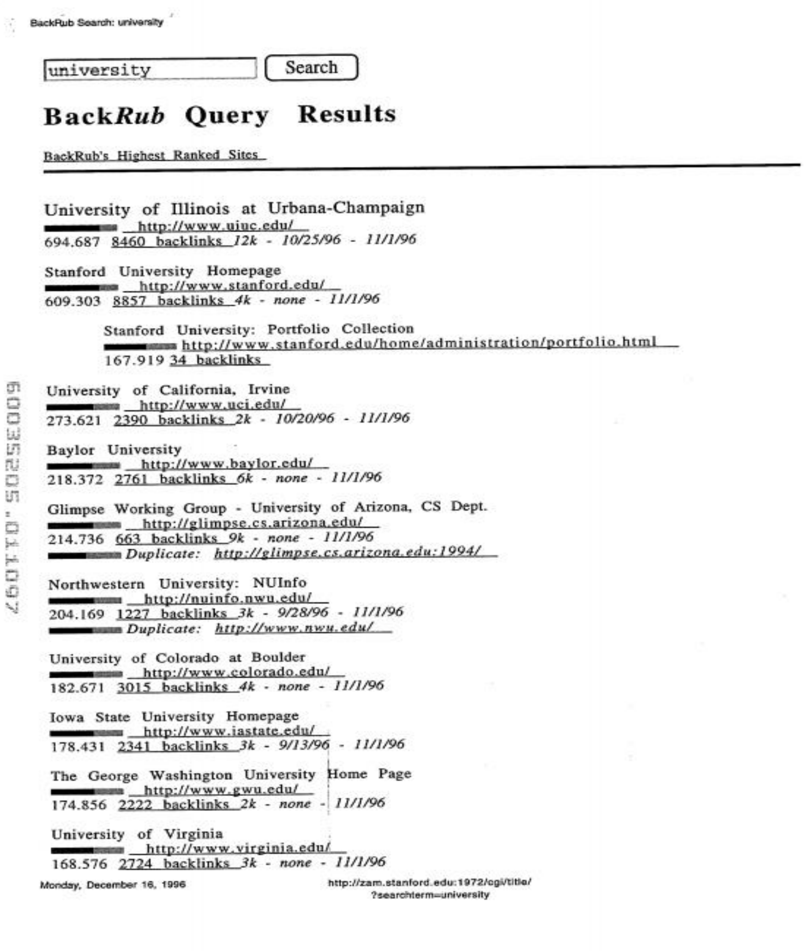

Figure 16: BackRub Search 1997: “university”. [24]

[22] https://www.wordstream.com/articles/Internet-search-engines-history
[23] https://en.wikipedia.org/wiki/History_of_Google
[24] http://www.seobythesea.com/improved-text-searching-in-hypertext-systems.pdf

With the advent of more powerful machines and better access to Internet (DSL diffusion[25]) new applications and new provisioning models started to emerge. The transition from mainframe to client-server infrastructures reached a peak of development during the year 2000 and with more service-oriented architectures, large Internet service providers started to transform.

In particular, platforms like Amazon, Google and many others required large infrastructure investments (servers) and computational resources (computer cores) to run global services, process increasing amounts of transactional data and perform core tasks and protocols. Their aggregations of data - mostly scraped in the case of Google and mostly originated in the case of Amazon - started to create masses of data hosted in private computational and storage islands that in order to respond more efficiently to users' requests had to be distributed and scaled globally.

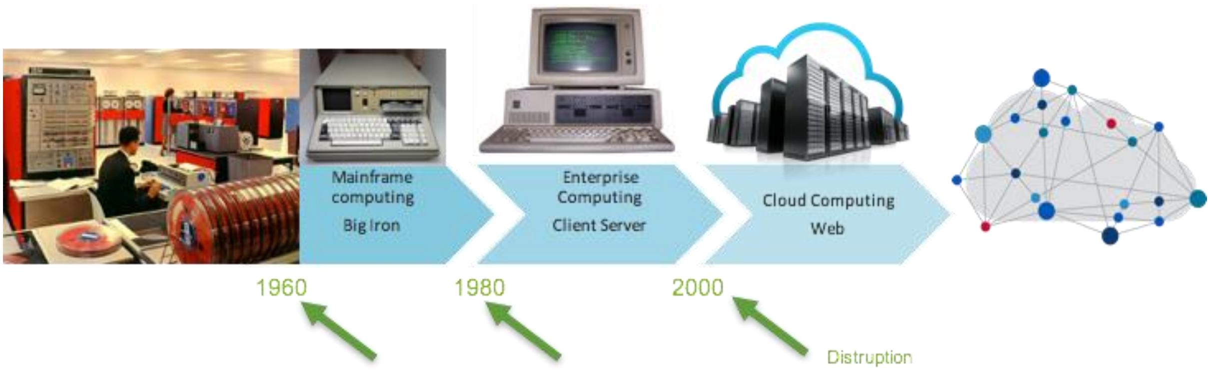

Figure 17: The Computing revolution.

This led to the creation of retail Cloud Computing (Mell et al., 2011) services that not only offered the possibility of clusters and virtualisation of those resources, but also offered a scalable way to design and develop new applications with less infrastructural investments. Cloud computing set the stage for the proliferation of global platform ecosystems. Companies such as Salesforce, Google, Microsoft and Apple capitalised on their infrastructure investments and started to plug into their business models other actors that obtained access to cheap computational resources.

The improvement of wireless networks and mobile devices expanded the ecosystem. The first mobile telephone technology, known as 1G, used brick-size analog phones (including AMPS, TACS and NMT4). This was followed by 2G, which supported more users within a cell using digital technology (including GSM, CDMA IS-95 and D-AMPS IS-136)

[25] https://en.wikipedia.org/wiki/Asymmetric_digital_subscriber_line

which allowed many callers to use the same multiplexed channel. 2G was primarily meant for voice calls. It didn't support data except SMS (Short Message Services). Nonetheless, with a software upgrade at the Base Transmission Station (BTS), 2.5G came to the picture and allowed carriers to offer higher data rates for customers who purchased compatible phones (such as handsets supporting GPRS). Then 3G offered more data transfer using larger bandwidth and opening up the broad range of Internet-based apps, user generated content and location-specific data, as well as sensor information from cameras, microphones, GPS and accelerometers.

Figure 18: The Mobile revolution.

The penetration of mobile phones, and mobile smartphone computers led by Apple iOS created new business opportunities, including app stores. The evolution was initiated by Apple (iTunes Store) in 2003, but the massive investments and the sustained efforts by all competitors shows the significance of such provider-driven platforms, allowing third-party app deployment and sales.

Virtually every mobile OS now highlights its own take on the mobile application storefront. Marketplace solutions differ in many respects, including how applications are structured, which search options exist, whether applications can only be bought on the phone or also on other devices (supporting cross platform app deployment), and whether recommendation systems and rating functions are supported. Originally launched in 2003 as a sales platform for audio content, the iTunes store was expanded in July 2008 with the Apple App Store, which was the first application store on the mobile app market and which has remained the leading position in volume, with currently 903,489 gaming apps and 3.06 million non-gaming apps available.

The iTunes App Store is the *de facto* standard for business model and monetisation since most of the apps require payment. The Google-based Android OS is the second major app store and represents an intentionally different approach than Apple's since, since it is not the only place where users can purchase Android apps. Google avoids alienating users and developers by removing or forbidding app categories, and by not coming into conflict with carriers, which are free to provide their own market solutions.

Mobile phone penetration is large and developers can make apps available immediately, the app can easily integrate with third-party software, virtually consume any type of data or service and give contextual information to users.

New network elements (sensors, gateway and actuators) that have been deployed by companies and are emerging in some cases as new mediated interfaces to the Internet offer an easy way to interact and check service status and collect and process users/service generated data to be consumed by other services. The Internet of Things (IoT) is a collection of technologies and notions that enable the interaction between physical objects, online services and users.

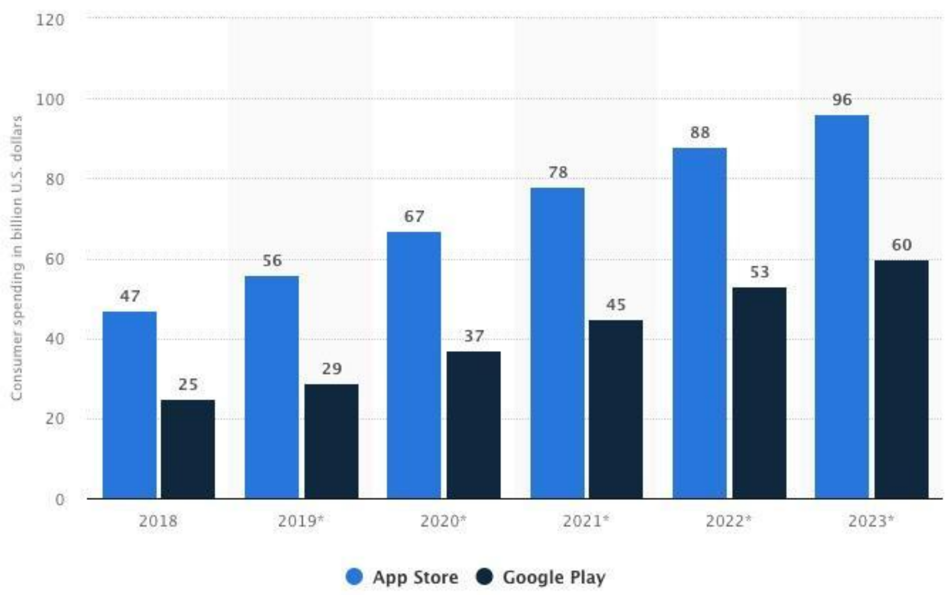

Figure 19: Forecasted Annual consumer per Operative system US (Statista).[26]

As a concept it opens up a new era of applications and services in many different domains. Connected devices in smart spaces offer more control and improve automation services. For instance: wearables track physical activity and vital signs; inventory and goods

[26]https://www.statista.com/statistics/747489/annual-consumer-spend-mobile-app-by-store/ curtesly https://www.statista.com/imprint/

in transit are monitored; cities provide more information to citizens about transport and resources management; and connected cars improve safety and reduce maintenance cost.

Embedded development has been advancing for decades, but connected devices have recently accelerated enormously moving, for example, from 46% penetration in the year 2000 to 82% penetration in 2019[27] in the UK. The huge market for miniaturised devices for mobile phones and the avoidance of lock-in provided by open source hardware and software has brought to the masses the introduction of embedded prototyping platforms (like Arduino, mBed, Spark core, Raspberry Pi, and many more). This allows individuals and businesses to quickly and easily prototype connected objects that communicate directly (or indirectly) with the Internet.

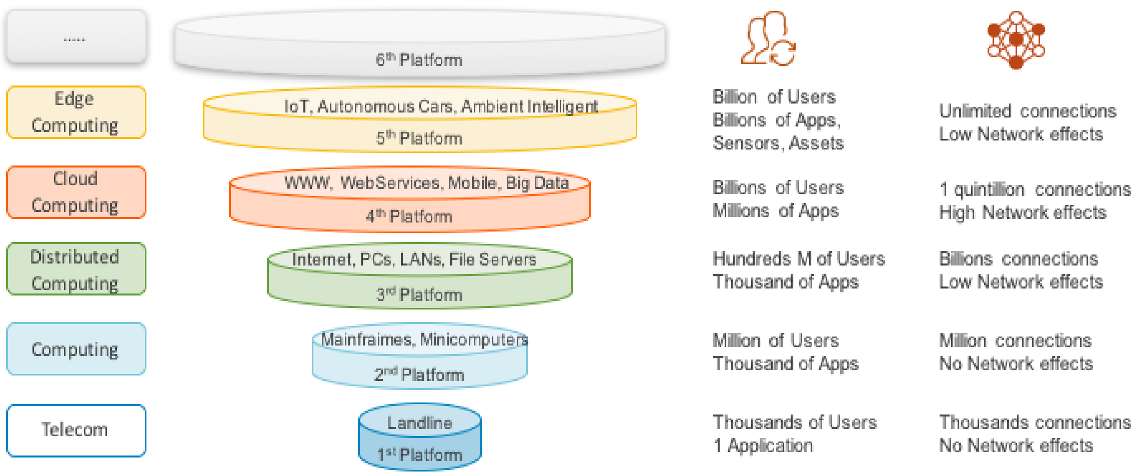

Figure 20: Network effects of platform revolution

Quick prototyping and the open market for devices has led to many successes, including crowdfunding campaigns (e.g, the Pebble smart watch, the SmartThings IoT gateway, the Spark core Arduino WiFi module, etc.), popular IoT company acquisitions (Nest, Basis and Ring). According to consultancies, IoT together with AI and blockchain is at the top of the hype cycle and there has been a considerable increase of new startups and SMEs seeking to get involved in the IoT commercial space by providing hardware and software solutions in the domains of home automation, wearables, mobility and smart cities. With the ease of access to the market, it is predicted that most of the IoT solutions in the market will originate from startups and small companies as demonstrated by the proliferation of startup companies producing successful devices (Pebble acquired by Fitbit).

[27]https://www.statista.com/statistics/274109/connected-device-penetration-in-the-united-kingdom-uk-since-2000

The picture above shows that today's information technologies are much more powerful and pervasive than those used during the 1980s and 1990s. At that time, tech platforms where installed, licenced and used as stand-alone solutions. They were expensive with strong hardware lock-in effects and very limited connectivity and integration capabilities. Even the Telco network was limited to calls and slow data transfer; real time collaboration other than by voice was prohibitively expensive since it required specialised equipment and communications infrastructure. Today, Internet platforms are very fluid, connected, offering a multitude of free or freemium applications, content, real time communication opportunities at low or no cost, supporting peer-to-peer networking, connections, immediate transfer of knowledge and value among users. Users can purchase digital and physical products from their home without visiting retail stores and can meet people digitally. All platforms also enable users to act as a quasi-producers or prosumers and create things themselves that were previously embedded in proprietary structures. The so-called gig economy involves digital platforms with efficient acquisition funnels leveraging the skills and assets of individuals.

The servitisation or servification[28] of the industry is blurring the difference between traditional industrial manufacturing activities and high value services (Helo et al., 2017). This makes it more difficult to track and trace measurement and contribution to GDP since networks, knowledge, data and value span across different sectors and jurisdictions in the networked economy. In contrast, GDP is aggregated vertically. At the beginning, the contribution of ICT to GDP growth was mainly focused on regulated Telco network and broadband penetration, but now new dimensions must be considered. The telecommunications network is becoming increasingly a commodity while the real value is moving towards the networks of applications and the capability to exploit data and ecosystems.

According to IDC (Reinsel et al., 2018), data sharing is growing very rapidly. They estimate that in 2025 data sharing will reach 175ZB of data. Connected societies will produce four times as much data as is generated today and this growth will be the result of the incorporation of intelligent agents that use machine learning and other forms of artificial intelligence to analyse the growing amount of data generated by the digital things. Artificial intelligence, Internet of Things and autonomous agents will be major drivers for a revolution similar to what web crawlers were for the initial World Wide Web age. As stated in the report, the data-driven world will be continuously learning from data collected, captured and monitored in cyberspace.

[28] https://link.springer.com/chapter/10.1007/978-3-642-39336-5_2#citeas

With the exponential growth of data, Clouds will play a stronger role than today. IDC stated that the Cloud is one of the key drivers of this growth and will handle most of the storage and processing on the Internet. Public Clouds will host more than 49% of global stored data, becoming *de facto* the new standard for enterprise and consumer data storage.

2.5. The Internet-Based Economy and Platform Disruption: Understanding Digital Ecosystems

Economic actors are adapting very rapidly to new market opportunities and technological enablement, by adopting new business strategies).

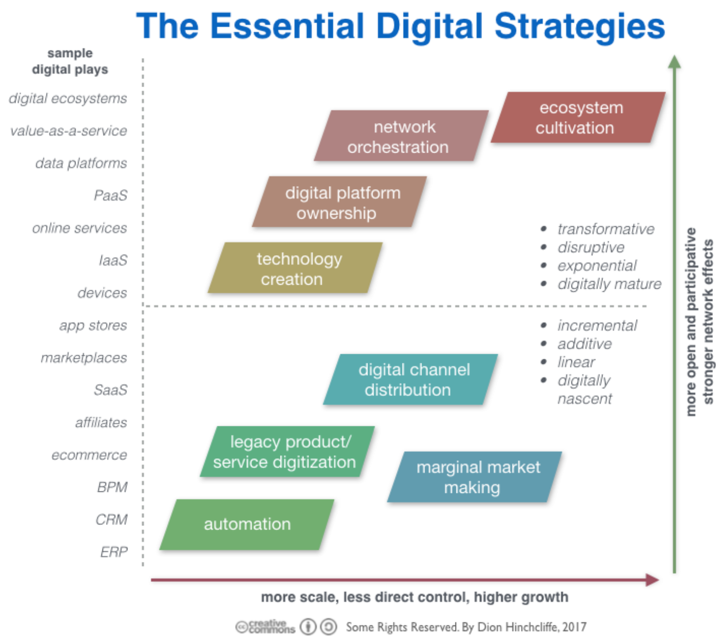

Figure 21: Digital Strategies (Hinchcliffe, 2017).[29]

Strategies include digital, leveraging new distributions and value-capturing models (Servification of the industries, Data economy) that exploit the technological advancements like Service Virtualisation, Microservices and Platformisation of organisations. Economic actors like Google, Amazon and Facebook drove those trends to create new collaborative models and business opportunities. This happened because they understood the value of data and the possibility to digitalise relationships and services, creating new opportunities for atomic transactions. They not only created new value proposition models, but they created complete ecosystems empowering their market strategy.

[29] https://dionhinchcliffe.com/2017/08/15/the-essential-digital-strategies/

Concretely, a digital ecosystem is the digital representation, with some additional characteristics, of what Moore (Moore, 1999) defined as Business Ecosystems. For Moore, a Business Ecosystem is:

"An economic community supported by a foundation of interacting organizations and individuals—the organisms of the business world. The economic community produces goods and services of value to customers, who are themselves members of the ecosystem. The member organisms also include suppliers, lead producers, competitors, and other stakeholders. Over time, they coevolve their capabilities and roles, and tend to align themselves with the directions set by one or more central companies. Those companies holding leadership roles may change over time, but the function of ecosystem leader is valued by the community because it enables members to move toward shared visions to align their investments, and to find mutually supportive roles" (Moore, 1996).

Table 2: Core reason for the implementation of Digital Strategies

Main reasons for the strategic shift	
Network effects	Production inversion
– platform value appreciates through use – ≠ product value depreciates through use.	–Users become producers and share surplus. –Platform have zero marginal costs. Not incurring the costs of production, they can scale as fast as they can add partners. –External labour force, no associated costs (-welfare), not counted among the traditional workforce.

By using an ecological metaphor, Moore emphasized the dynamics of such relationships and how those entities are developing mutually beneficial ("symbiotic") relationships and opportunities within an ecosystem. On the ecological analogy, companies that co-evolve will flourish while companies that are not able to keep up with the pace of innovation will die and be replaced by stronger species.

It is important to emphasise here that a company operating in a specific ecosystem can influence or even set the conditions for the action of new actors that can envision in a new niche market the opportunity to drive their value proposition faster. In this situation the new actor's offering will be dependent on the other company output and the two companies will co-evolve together.

Inspired by those ideas and by the increased adoption of ICT technologies by companies in the world in 2002, Francesco Nachira, a project officer from the EU Commission (DG INFSO), formalised a research programme on the so called Digital Business Ecosystem (Nachira, 2002). In the context of a business activity, a Digital Ecosystem has been defined as a distributed, adaptive, open socio-technical system with properties of self-organisation, scalability and sustainability inspired from natural ecosystems. A collaborative digital infrastructure creates favourable conditions for value creation, competition and collaboration among diverse entities or species (Nachira et al., 2007). Therefore, a Digital Ecosystem is an information-mediated infrastructure where intangibles are created, shared and re-mixed, and where they can be executed and consumed by internal and external contributors.

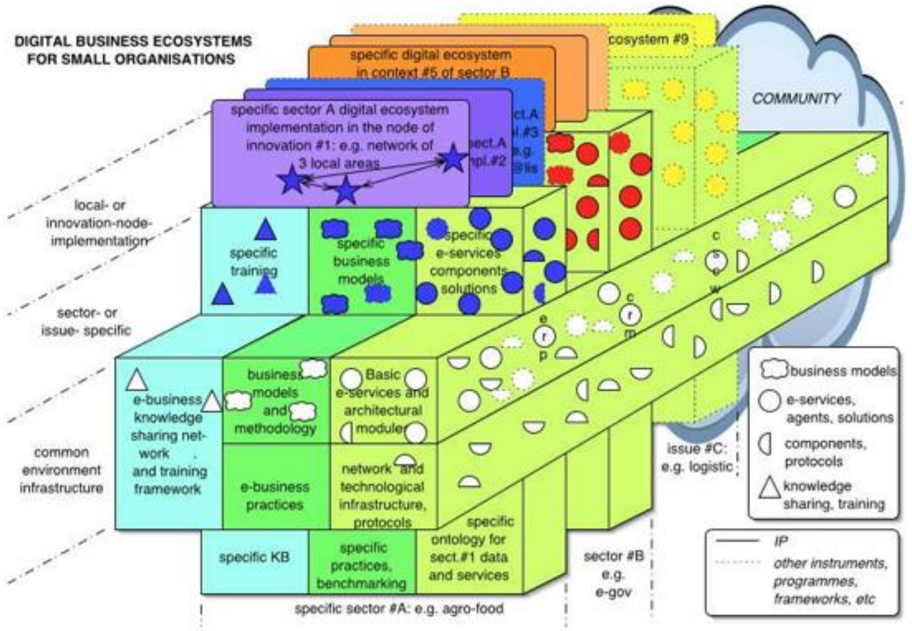

Figure 22: Digital Business Ecosystem (Nachira, 2002).[30]

A Digital Ecosystem can be totally open or mediated and can facilitate the creation of cascading effects, as in a biological ecosystem. Companies like Amazon, Google and Facebook understood early, contrary to Telco operators, the advantage to opening up their infrastructure to third parties, startups and developers. Those companies decided to offer their digital platforms, sometimes for free, with the objective to create a rich collaborative digital ecosystem that could increase the overall value of their company's assets, acquire new data to improve their go-to-market strategy and their network virality, create new lock-in effects, and increase the channelling of new products and services to their users (Figure 22).

Google, Amazon, Microsoft and Salesforce moved from being applications running over the Internet to platform ecosystems with a full stack of developers, storage and processing services. They developed digital strategies to create a large ecosystem of consumers and producers utilising their services, favouring the creation of large data flows and enabling the possibility to learn from data consumed and produced in their ecosystem.

[30] http://www.digital-ecosystems.org/refs/2002_dbe_discussionpaper.pdf
http://creativecommons.org/licenses/by-nc-sa/3.0/

They created a new layer (Figure 23) to facilitate aggregation and quasi-oligopolies by demand economies of scale (Shapiro et al., 1999).

A successful example of this digital strategy is Amazon Web Services.[31] Amazon developed a very advanced web service infrastructure to facilitate internal collaboration and data sharing among different functions of the Amazon website. Amazon decided to move away from a monolithic approach to technology architecture and into a mix-and-match paradigm, where programmable cloud infrastructure and Application Program Interfaces (APIs)[32] have become a key component for success. APIs are digital ports expose sub-functions, or small applications that allow developers to facilitate integration among software projects and use data and services seamlessly. With APIs they can use different tools in a single solution by enhancing communication between different components. With the innovative cloud infrastructure and all the APIs they released, Amazon decided to facilitate the creation of virtual servers at their premises and expedite communications between all business functions and software, enabling developers to create new software by combining those digital assets to work as if they were a single program.

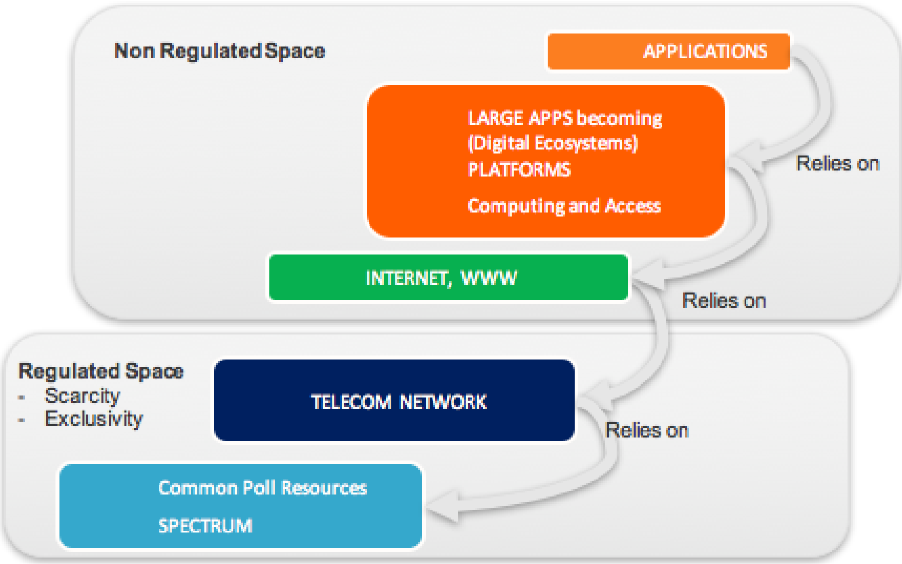

Figure 23: The new internet stack.

This new infrastructure, called Amazon AWS, became so powerful that it could be offered to others, and because of the scale and time-sharing capacity, it could be offered at very low cost. Developers and small and medium-sized companies could, instead of buying servers and hardware, present their offering on the Internet using cloud infrastructure.

[31] https://aws.amazon.com/
[32] https://en.wikipedia.org/wiki/Application_programming_interface

Amazon began to offer additional functionalities, but also relied on other companies to offer digital services for developers to make their work faster and more effective. Those companies were able to acquire Amazon clients rapidly and realised the power of common standard infrastructure that improved their sales funnel and margins. The companies, increased their offerings to the marketplace and caused some of their clients and infrastructures to move into the Amazon ecosystem.

Amazon increased the marketplace capabilities and acquired new customers and started offering new functionalities to connect third-parties. Amazon transitioned from being an e-commerce service provider to a technological and logistic platform for companies to do business with one another and one another's customers. This strategy was very successful. Amazon became one of the highest capitalised companies in the world, and gained the possibility to enhance the technical infrastructure, relying on internal and external clients, giving it strategic advantage over others, and the possibility to digest, process and enrich data that has been used to train new tools like Alexa, enabling new business models and opportunities.

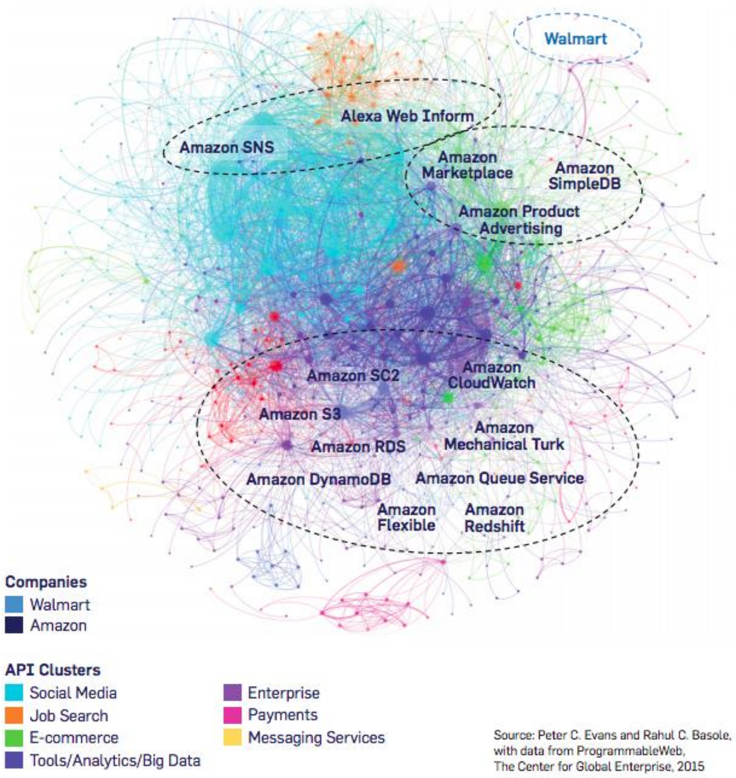

Figure 24: API Ecosystem (Evans & Basole, 2016).

In 2016, Evans and Basole published a paper about "Revealing the API Ecosystem and Enterprise Strategy via Visual Analytics"[33] (Evans & Basole, 2016). In this paper, they explained how the application programming interface (API) of companies can explain their digital strategy and how they are positioning in the market. In this case, we can see how Amazon has been extremely efficient in developing a full ecosystem of relationships via APIs. In 2016, Amazon had 33 official APIs published and more than 300 mashups were created as a combination of Amazon APIs and other APIs. This compares with Walmart, another retail giant that only published one API (Figure 24). Some of those ecosystems are centralised and private, managed by a catalyst that has a strong technical or commercial interests like SAP, Google, Amazon, Facebook and have interfaces with other providers. They can offer basic infrastructure services and applications, and provide data-brokering services that stimulate the interconnection between communication, data and value creation.

The basic enabler of those ecosystems are APIs. But while they facilitate the creation of an interconnected ecosystem, the proprietary nature of the platforms reinforce strongly centralised control mechanisms on data and value creation. Consider, for instance, an entrepreneur who offers food delivery. If the entrepreneur uses one of these platforms, the platform provider collects data about entrepreneur's customers. For instance, if the software developer decided to use the Google Maps APIs, Google gets the information collected by other apps that use its API and has the sole rights to monetize it. This gets even stronger with applications like Uber Eats, which simply by providing delivery and payment functions, obtains the actual relationship to the customer.

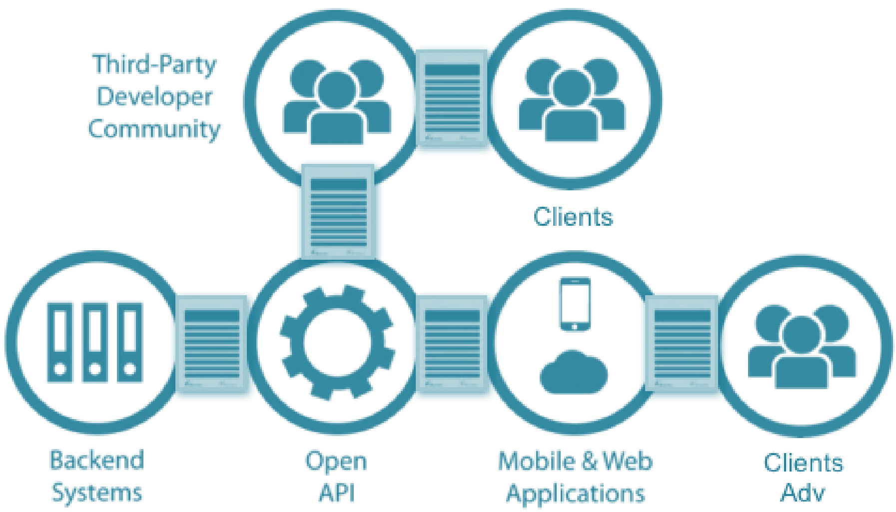

Figure 25: Contracts in SaaS based Ecosystems.[34]

[33] http://entsci.gatech.edu/api-ecosystem/
[34] Adapted from @yourapi_io

Notably, under the GDPR[35], the food service becomes a "service provider" to Uber Eats; the customer-supplier relationship with the delivery service is inverted (Parker et al., 2016). This is generally reinforced by terms of use; to access an API developers have to sign agreements define restrictions, proprietary and IP rights, indemnification, limitation of liabilities, data usage and fees. The monitoring of events, or APIs calls, connected with billing systems is managed by transactional systems like 3Scale, a RedHat company that offers AAA cloud solutions to companies with the objective of streamlining their ecosystem and monetisation capabilities. In this situation, the relationship between the contracts and the events are loosely coupled since those contracts are not computable and do not monitor real time the execution of the service for compliance purposes.

The Internet can be considered as a *Global Digital Ecosystem* with specialised communities as sub-ecosystems within this global ecosystem. The technical enablement, the technical infrastructure on top of the Internet that facilitate the interaction of those species within a specific community, can be very different and even the governance of those communities can vary. Below we can find some characteristics of those digital ecosystems:

Table 3: Core Characteristics of Digital Ecosystems

Characteristics	**Enablers**
Non geographically bounded	

-Low Scalable investments
-Agile and Adaptive
-Rapid Growth
-Dual Sided Strategy
-Lock in effect
    -Computing
    -Services
    -Data
-Disruptive Business Models
	Cloud
	-APIs (Contracts)
	
	-Network Effects
	-Symbiotic Relationships
	-Apps providers
	-Users Become Prosumers
	-Part of the production cycle

Demand economies of scale differ from supply economies of scale because of technology development on the demand side. Demand-side platforms are driven by efficiencies in social networks, app development, sharing and other techniques that make larger networks more valuable to their users. The platform achieving a solid network effect can obtain a solid advantage that is difficult to overcome (Parker et al., 2016).

[35] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32016R0679

The ITU (ITU, 2018)[36] in its latest study confirmed that the impact of digitalisation and digital ecosystems on GDP is positive and contributing more than the broadband penetration, like the impact of mobile broadband (*increase of 1% of digital ecosystem development index results in 0.13 per cent growth in GDP per capita*). The ITU also confirmed an economic impact on productivity (both labour and total factor). An increase of the index of 1 percent yields an increase in labour productivity of 0.26 % and in total factor productivity of 0.23 per cent. This is true more for developed countries that developing ones.

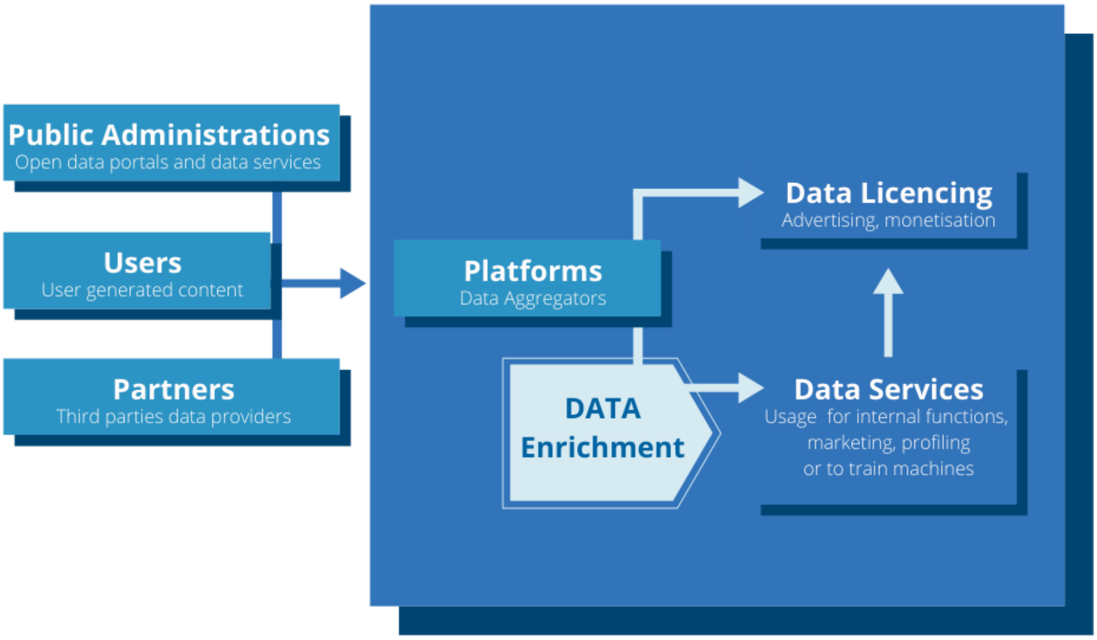

Figure 26: Creation of the value of data.

Digital platforms have been offering digital goods and services for free or with very appealing freemium models, or even with substantial subsidies such as for Uber, to achieve high network scale and to create moats for data or content on their ecosystems. For instance, for Facebook the usage of the platform is free and users participate actively to access such a platform. But free doesn't mean that there is not an exchange of value. Something is exchanged:

> *"(...) consumers, in fact, exchange their personal data for 'free' digital goods and services, and the Facebook–Cambridge Analytica data scandal demonstrates that there is no such thing as a free lunch in the digital economy"* (Li et al., 2019).

All those free digital products are challenges to policy makers, macroeconomists and accountants, who are used to evaluate assets based on prices paid. Big platforms do monetise data and data can be enriched and create many other by-products, but the value at stake is

[36] https://www.itu.int/en/ITU-D/Regulatory-Market/Documents/FINAL_1d_18-00513_Broadband-and-Digital-Transformation-E.pdf

unclear (Figure 26). One problem is data accessibility from those large providers (Demunter, 2018) and another problem is that data has intangible value and is difficult to be accounted for using the International Accounting Standards.[37]

“Unlike R&D assets that may depreciate due to obsolescence, data can create new value through data fusion and innovations in data-driven business models – unique features that create unprecedented challenges in measurement.” (Li et al., 2019).

Investors understand the value of data and network effects and they are willing to pay more if start-ups and companies are able to create defensible mechanisms, even if they are invisible to accountants and policy makers. Furthermore, those mechanisms enable the possibility of leveraging their networks for “production inversion” (Parker et al., 2016). Production inversion means that instead of internalising production factors, like labour and asset, the platform leverages their users’ resources to create a two-sided market strategy.

		Start Year	Number of Employees	Market cap (Billion $)
BMW / MINI	One of the most famous car company in the world	1916	131,000	51
Uber	Largest taxi company with no vehicle	2009	16,000	76
Marriott HOTELS · RESORTS · SUITES	One of the most renowned hotellerie company in the world	1927	177,000	39
airbnb	The world largest accommodation provider with no rooms owned	2008	10,000	38
Walt Disney	The most famous multi channel content producer in the world	1923	199,000	163
FACEBOOK	The world most popular media owner that does not create any content	2004	35,000	473

Figure 27: Characteristic and impact of digital platforms vs traditional firms.

These digital platforms actively try to externalise production factors and use their users’ assets to reduce production costs, create lock-in effects and increase wealth and margins, in the “gig economy.” Most of those mechanisms are therefore difficult to track, because connected with intangibles and external structure (network) management (digital companies are increasing the weight of one of the dimensions Sveiby (Sveiby, 1998) described as External Capital - Structure). GDP and capital gains are embedded in digital protocols capable of controlling distributed contributions, under-utilised assets and human

[37] https://www.ifrs.org/

resources that will be never accounted as direct employees for those companies but will directly contribute to the generation of wealth at very low marginal cost. All this is clearly visible in Figure 27.

The case of Uber is in this context very relevant. An economist studied the valuation of the company, arguing that pre-money valuation before IPO was not aligned with the market perspective and the unit economics of the company (Damodaran, 2014). This analysis triggered a response from an investor (Gurley, 2014) that explained how the spreadsheet prepared by Damodaran was not correctly considering network effects since it was based on traditional company valuation models.

Most of these platform applications and services are hosted and operated on public clouds where data is processed and stored and where small startups and large enterprises can extract better information from their data using Machine Learning and Artificial Intelligence building blocks from those large market players. Google, Amazon and others have access to growing computational capabilities and are training their machines with the help of all the data producers and data scientists using their services.

Digital ecosystems, enabled by cloud distribution models and easy to access APIs, are therefore in a strong position. They intermediate relations and process large volumes of data that can be translated by the right methods and tools into information and eventually knowledge (Bellinger et al., 2004). These platforms are obtain large network effects (more users join a network create a unique value to other users) and economies of scale (the cost of producing a new unit is smaller if we have higher outputs). Processing more data is a useful exercise that does not cost much and helps train their machines with other people's data.

2.5.1. The Emergence of Distributed Cryptographic Business Ecosystems

On the other side of the spectrum, there is fully decentralised, peer-to-peer cryptographically-based infrastructure, like Bitcoin (Nakamoto, 2008) the first blockchain ever created or Ethereum. That technology is fully open and accessible, and the community governance and contribution is open and transparent. Don and Alex Tapscott stated this as:

"The blockchain is an incorruptible digital ledger of economic transactions that can be programmed to record not just financial transactions but virtually everything of value." (Tapscott et al., 2016).

In a blockchain-based application the information usually is not stored centrally, but rather distributed simultaneously in the peer-to-peer infrastructure (Figure 28) and replicated to every node's ledger, a chronological list of chained transactions, creating a fully trust-capable network dynamic. Blockchains can also use APIs, and most of the distributed applications mix centralised and decentralised components, using the data replication mechanism offered by a blockchain to ensure that users remain independent of gatekeepers. This fully-distributed approach is closer to the original Digital Ecosystem concept and implemented by projects like the Digital Business Ecosystems (DBE), the Open Negotiation Environment (ONE) and others that were part of the cluster and anticipated the advent of blockchain-based infrastructures.

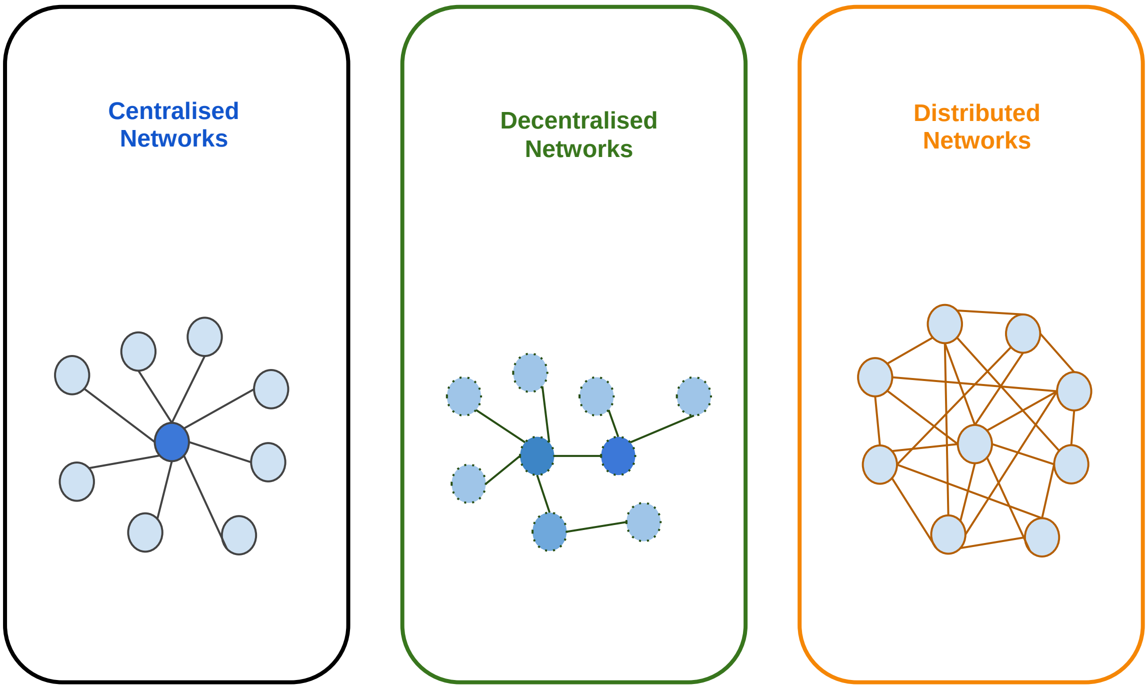

Figure 28: From Centralised to Distributed Ecosystems.

In blockchain, all transactional aspects are transparent and replicated with a consensus mechanism. Consensus mechanisms can be different in each blockchain infrastructure, ranging from Proof of Work, to Proof of Stake, Proof of Authority and many others consensus protocols, offering different governance mechanisms and transaction throughput (Zheng *et al.* 2018). In a private blockchain implementation, trust among the participants is substituted for expensive cryptographic mechanisms, like Proof of Work, to ensure security among peers.

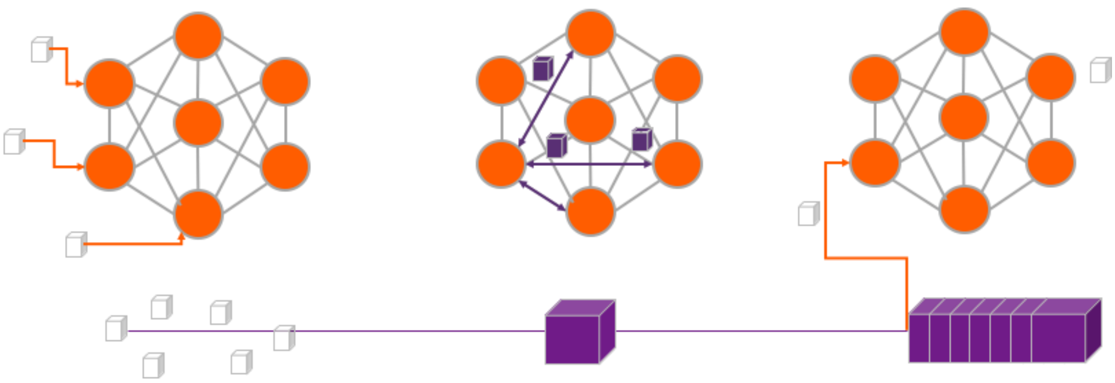

Figure 29: Transactions and Block-Propagation in Blockchain.

The relationship between commitments, verification means and transactions in this distributed infrastructure is governed by “Smart Contracts.” Smart contracts have been adopted by blockchain communities, but were first proposed by Nick Szabo as computerized transaction protocols that execute terms of contract (Szabo, 1994, 1997). In his paper, Szabo proposed the execution of a contract for synthetic assets such as derivatives and bonds. Szabo explained that:

“Smart contracts go beyond the vending machine in proposing to embed contracts in all sorts of property that is valuable and controlled by digital means. Smart contracts reference that property in a dynamic, often proactively enforced form, and provide much better observation and verification where proactive measures must fall short.”

Although the term “Smart Contract” was coined in 1994, it became popular with the present implementations based on blockchains and distributed ledger technologies and in particular with Ethereum. The term “Smart Contract” is now mostly used in the sense of general purpose algorithmic modelling of a business interaction that takes place on a blockchain in a distributed manner. A Smart Contract can therefore be used to automatically measure activities, process transactions, represent and manage commitments and digital assets online.

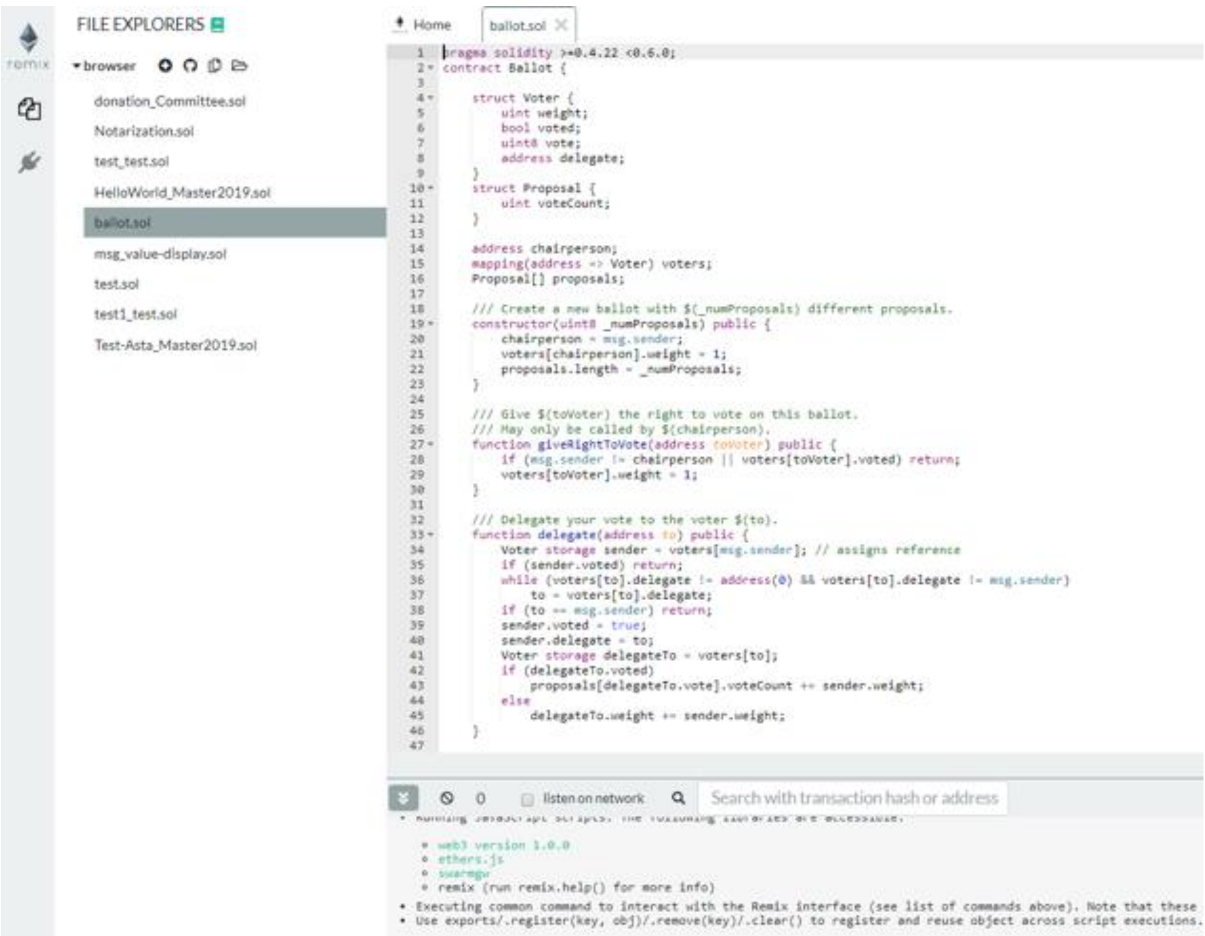

Figure 30: A ballot Smart Contract in Remix (Ethereum).

Smart Contracts in their pure, permissionless blockchain form attempt to avoid the difficulties of drafting, interpretation and enforcement by reducing all of the performative elements of contracts to code and all of the remedies to transfer of tokens held on the blockchain. The thought is that code can be unambiguous, that many transactions have clearly-defined goals and that a transfer of a specified value can compensate for any failure. There are examples of such systems - including on blockchains and in systems such as Digital Rights Management. Bitcoin functions this way.

But there are both theoretical and practical reasons to doubt that contracts can be comprehensively defined in code if they have i) more than very minimal complexity, ii) impact beyond the blockchain itself, or iii) systemic importance. The theoretical doubt is expressed in the Nobel-winning work on contract "incompleteness" by Hart and Holmström[38] (Hart and Holmström, 1986), and in lawyers' daily experience of things gone wrong. A practical demonstration of the limits of blockchains is the succession of mishaps in the various blockchain ecosystems.[39]

As people began to implement Smart Contract systems, it become obvious that the only kinds of transactions that could be purely code-based and "self-enforcing" were those that related purely to tokens of value represented on a blockchain, *e.g.*, in the bitcoin blockchain, transactions in Bitcoins could be self-enforcing. But there were problems even with these kinds of transactions when the code did not behave as expected. A notable example was "The DAO"[40] debacle on Ethereum. A programme vulnerability was exploited by a hacker to take a large part of the value, a behaviour did not match the "intention" of the developers, the contract subscribers and most of the community. Key players in the community decided to roll-back the database, revealing that the system was not "trustless."

Most real-life contracts cannot be fully expressed as algorithms; real contracts are inherently "incomplete" and are intended to have consequences beyond the ledgers.

Where there is a strong rule of law, a digital contract does not need to be "complete" in the Hart and Holmström sense. It can, like conventional automated order systems, have elements that are expressed in code such that machines can automate the normal flow of the contract, while unanticipated and edge cases are handled by discussion among the parties, by allocation of decision to one party (based for instance on "ownership" as Hart describes) or by

[38] Any actual contract cannot as a practical matter specify all possible eventualities. A critical efficiency is to specify who makes the decision. This is the role of notions such as property rights and of dispute resolution. https://www.nobelprize.org/uploads/2018/06/advanced-economicsciences2016-1.pdf
[39] Most famously, "The DAO" debacle of 2016 -https://en.wikipedia.org/wiki/The_DAO_(organization)
[40] https://en.wikipedia.org/wiki/The_DAO_(organization)

legal dispute resolution. This is how most electronic marketplaces, stock exchanges and web merchants work.

The major problem of these systems is not proof or enforcement, it is capture of excessive value by the market hosts. The advantage of a blockchain approach is that it can facilitate having a marketplace be maintained among a group of stakeholders rather than by a single host.

In these real world uses where the legal context has to be specified to give more clarity to the governance of the contract, the solution is to pair digital code with legal templates in a format called "Ricardian contracts"[41] after the work of Ian Grigg (Grigg, 1997, 2000).

[41] https://iang.org/papers/ricardian_contract.html

3. LOOKING THE ECONOMY THROUGH DATA AND CONTRACTS FOR SMART POLICY MAKING[42]

3.1. Introduction

A unifying element of our study is the role of modelling and how an efficient method for modelling contracts could facilitate the efficient functioning of the European economy as well as its measurement and regulation. In this respect, it parallels enterprise efforts at “contract management”, “supply chain management” and “digital ecosystem management.”

Measurement is critical to effective operations. It is increasingly possible because of data capture and processing systems such as IoT, encrypted data and big data systems. These systems provide immediate operational information for automated actions and are aggregated to make more complex decisions and to optimize operations. They are increasingly used by businesses and others to manage their affairs, develop strategies and report. However, even within an enterprise (a sub-ecosystem of employees, suppliers and customers) the lack of common syntax and semantics makes it impossible to have a comprehensive view.

While these systems should benefit all businesses, governments and the population as a whole, much of the benefit has been captured in large businesses that have great network effects. This creates numerous difficulties and dangers, and reduces the ability of the general public and its representatives to understand, make choices, obtain the value of and regulate matters critical to their future.

The measurement issue is at the core of the trend toward gigantism in the digital economy. In a world dominated by the internet and technology giants, a challenge for the European Commission and other policy and regulatory bodies is related to the inaccessibility of data and inconsistency of current indicators in supporting the legislative and decision activities in many different policy areas. In particular, with the advent of the digital economy, assessing the impact of a change in rules can be challenging. As an example, some regulations impact the relative importance of actors in networks, because of a variety of reasons (competition, consumer rights or other). The changes and impact may be difficult to see or predict using GDP since it does not integrate the value of data produced by networks and market structures, which are increasingly intangible and digitalised.

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[42] This chapter was written by Luigi Telesca, James Hazard, and Mahfuzul Islam with contributions from Ali Hassan and Jukka Huhtamäki; the authors acknowledge helpful comments and suggestions of Francis Gross (European Central Bank), Tim Cummings and Sally Guyer (IACCM), Stefano Federico (Studio Federico – Ordine dei Commercialisti di Roma), Helena Haapio (Lexpert), Marianne Paasi (TU Berlin), Rory Unsworth (SwissRe), Ines Curtius (Airbus), Thierry Perrouault (Orange), Jeremy Rollison (Microsoft).

In evaluating and justifying policies, the EC needs to demonstrate the impact on GDP. But the impact is difficult to predict because the changes are not directly mapped in the measurement framework. Since in GDP the demand structure is particular stable (demand for a particular good or service) it does not integrate the changes in the market structure (for GDP the type of platform on which the product/service is consumed is irrelevant). An example of this is the transformation of the music industry by new platform delivery models (iTunes, Spotify) or with Open Source distribution of tools (*i.e.*, mobile software apps on Android). A purely GDP view makes it impossible to understand the reasons for the growth or decline of specific industries.

A better framework for policy-making and monitoring can be made by leveraging data beyond current economic indicators. These new streams of data can be efficiently analysed in detail and enhanced with network and contract information to give a better model to understand, test and assess the impact of policies that EU institutions might implement.

This report evaluates and analyses how an innovative approach can be used both for reporting the EU economy as an ecosystem of contracts and as an actual way to effectuate the connection between legal, accounting and automation models, creating a boundary object between these worlds. It can also help guide the convergence of online transacting and IT into socially responsive and sustainable models. The approach demonstrated draws on "Social Physics"[43] (Pentland 2015) as well as decentralized access control, smart contracts and object-oriented programming. It is more efficient, less centralised and has the ability to provide precise, qualitative and quantitative measures of contracting across the entire EU economy. This "contract" ecosystem can facilitate and make measurable and visible the way intangible assets and data should be correctly accounted in the European open ledger of value.

In this chapter, we discuss:

1. A theoretical approach to analysis called C.I.S.G. (Communities, Infrastructures, Services, Governances).
2. The core dimensions to analyse the EU Economy as an ecosystem of contracts.
3. The history and context of conventional contract technology, "smart contracts" and "Ricardian contracts" as an expression of an ecosystem of transactions and relationships.
4. Leveraging open source methods and a contract data model (prose objects) to federate current trends in IT into a standards-based, secure, decentralised approach to transacting (Social Physics).

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[43] https://www.penguinrandomhouse.com/books/314230/social-physics-by-alex-pentland/9780143126331/

5. A sketch of a graph-based contract ecosystem and the Open Trust Fabric concept.

6. A detailed analysis of data methods that could be used to model the economy as an ecosystem of contracts.

3.2. Analysing Ecosystem Structures

In order to provide a common structure for this multidisciplinary study, we analyse contract ecosystems and related infrastructures under the umbrella of socio-technical studies, in particular referencing the theory of infrastructures that we believe provides a clear structure to study the multidimensional aspect of the role of contracts in today's economy.

In particular, we decided to use a multidisciplinary framework that refers to the work done by Susan Leigh Star, et al. (1996) showing the need to consider infrastructure with an ethnographic approach using a relational perspective (Star & Ruhleder, 1996). This is different from a mechanical perspective that interprets infrastructures as technological substrates of networked services failing to capture complex socio-technical relations and offering a biased and incomplete view of contract ecosystems. A better view is to consider contract ecosystems and infrastructures as artefacts emerging from practice, directly connected to human activities and material structures.

Therefore, we used the multidisciplinary framework called C.I.S.G. (Communities, Infrastructures, Services, Governances) (Botto & Passani, 2007) that offers a specific analytical framework based on the socio-technical theory of infrastructure. This is very useful for us to classify not only the contact types but also the underlying relations between contract artifacts and any kind of socio-technical infrastructure ("STI") connected to economic development and innovation.

The elements that play a pivotal role within innovative socio-technical processes related to ICTs are potentially infinite. Botto & Passani defined four dimensions that we adapted to our research case (Figure 31):

- Communities;
- Infrastructures;
- Services;
- Governances.

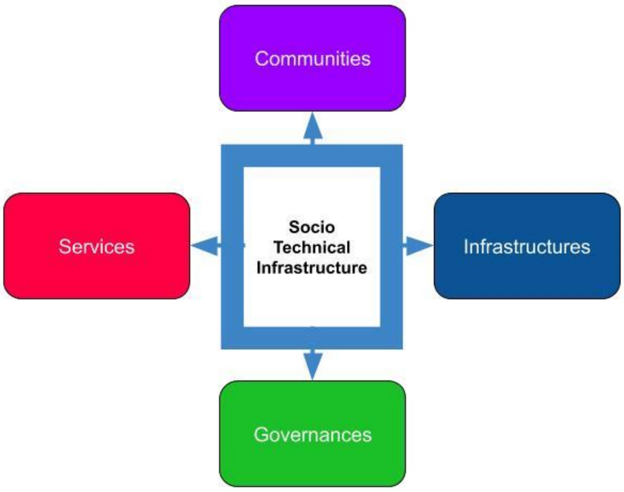

Figure 31: The C.I.S.G. framework for Socio-Technical Infrastructures.

In the following sections, we briefly describe the four dimensions using further sub-dimensions. Those sub-dimensions have only indicative character. We will use the sub-dimensions that emerge as relevant in the analysis of the contract's ecosystem and we will extend them a bit to fit our purpose.

3.2.1. Communities

The stakeholders that participate in an innovative ecosystem may vary in nature and role (Bijker & Pinch, 1987). In our case, we can draw up a long list of stakeholders involved and influenced by contracts and infrastructures that can be divided overall into three subgroups: citizens, businesses, governments (Figure 32). The parties to a contract are tightly connected to those subgroups.

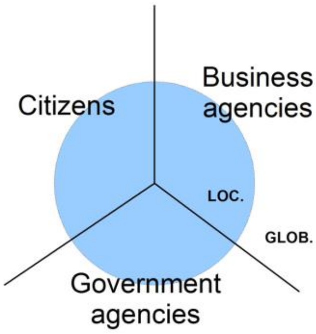

Figure 32: "Communities" in the C.I.S.G. framework (Botto & Passani, 2007)[44].

Citizens can be individuals, associations, or any group of people. In any case, each group is characterised by some sort of interest in STI, either implicit or explicit for their action. Business agencies can be either the business associations, companies interested in STI as the

[44] http://creativecommons.org/licenses/by-nc-sa/3.0/

object of their business, or companies looking for new services. Government agencies are those linked to the Public Administration, which take part in the STI. The communities involved in an STI may belong to the local or global context as indicated in Figure 32.

3.2.2. Infrastructures

The term *infrastructure*, as a dimension of the C.I.S.G. framework, represents the most technological element of STI infrastructure and considers the hardware (paper based) and software infrastructure parts together.

By *Hw infrastructure we* take into consideration elements such as physical documents, physical archives and local / physical servers (isolated or in clusters) and related components of these technologies with their respective standards.

Sw infrastructure includes all those computer programmes that allow a contract to operate and offer/control services' execution. This way, according to the details of the analysis, we can consider single applications hosted by virtual machines, middleware, network of peer to peer nodes as blockchain[45] and other software macro-elements, and/or their components as single code lines and their standards. The infrastructures implied in an STI constitute a network of elements within a local-global continuum (Figure 33).

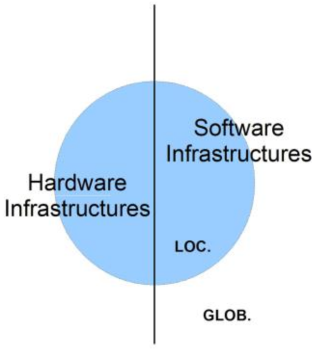

Figure 33: "Infrastructures" in the C.I.S.G. framework (Botto & Passani, 2007).

3.2.3. Services

The production of services for communities constitutes the main aim of any infrastructure. Considering the case of ICT-based STIs, we refer to on-line services such as connectivity or more advanced services such as communication, as well as specific services for e-Banking and e-Business. At this level, we can differentiate between services as on-line and off-line. *On-line services/assets* are those directly operating thanks to infrastructures. *Off-*

[45] Every middleware or p2p network as every blockchain as a mix of HW and SW Infrastructure, but the SW component is more relevant here since the HW can be "hired" by third party's providers.

line services/assets can be assets already available delivered via *off-line* services or physical assets that can be represented (digital self) and managed on-line via a service on a specific infrastructure; this represent second-level innovative services that impact the economy.

Again, as a general rule for services, it is not possible to define the local or global context without the help of a specific case, although the global context must always be considered (Figure 34).

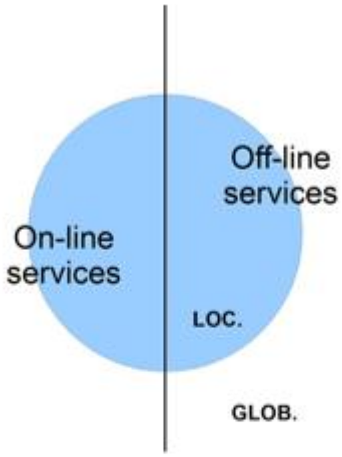

Figure 34: "Services" in the C.I.S.G. framework (Botto & Passani, 2007).

3.2.4. Governance

The term *Governance* has different meanings in the field of social sciences (Rhodes, 1996); in C.I.S.G. it refers more generally to the use of authorities, structures and institutions by means of which actors control and/or coordinate a specific activity, and at this level we can consider grassroots governance, corporate governance, and "government governance". *Grassroots governance* refers to the self-government of citizens on STI, on which they directly exercise their power. An example is the creation of a public blockchain infrastructure self-managed by private citizens who decide to manage their savings without a bank. *Corporate governance* is how business agencies govern the STIs under their control.

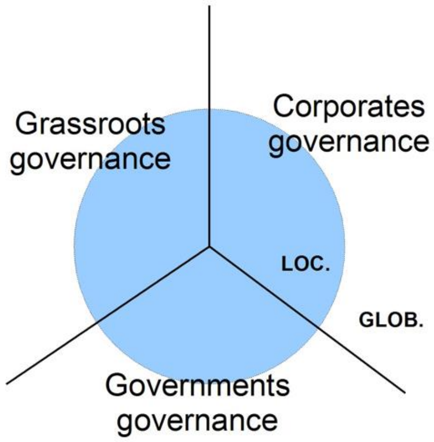

Figure 35: "Governances" in the C.I.S.G. framework (Botto & Passani, 2007).

An example is the activity of Cloud Providers that regulate and manage company infrastructures used by other actors. Government governance is how a government agency manages innovation in its territory. For example, the definition of regulations for a local government that uses a public information infrastructure. For governance we can again consider the local-global continuum represented in Figure 35.

3.2.5. The Relational Character of the Framework

The C.I.S.G. framework has been designed to study STIs under a multidimensional and relational perspective, thus reminding the researcher that the definition of each element must be settled with reference to its relation with the other elements. The analysis of such relations may provide an added value to the study only if contextualised, by explaining actual complex relations and continuity among elements of specific cases.

For the C.I.S.G. framework we can lay down three levels of abstraction:

- *Relational description at abstract framework level:* useful as theoretical-methodological explanation on the nature of the framework.
- *Relational description at the level of specific types of STIs:* useful for descriptive and comparative purposes between different phenomena.
- *Analysis of specific case studies for STIs:* it allows the researcher to analyse some contexts in greater depth, such as the platforms like Amazon or Google ecosystems.

From a theoretical-methodological point of view, we can generally describe the relational characteristics of the C.I.S.G. (Figure 6) framework as follows:

1. *Communities*. Created independently or co-created in cooperation with other agencies, infrastructures (I) and services (S) for personal objectives. They can build up their own types of governance (G) and, if needed, ask the public administration to put into practice and control specific governance models or frameworks;

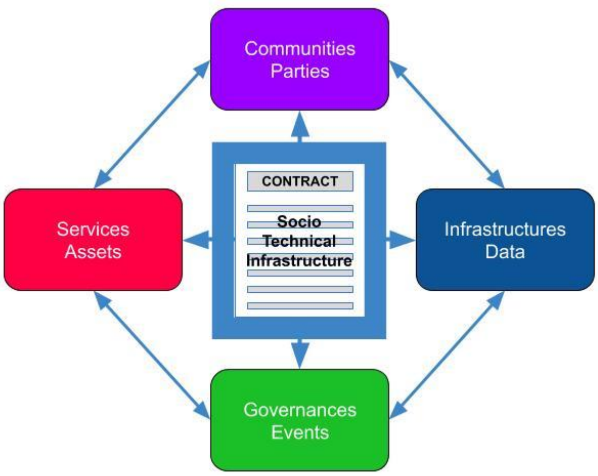

Figure 36: The C.I.S.G. framework for contract ecosystem modelling.

2. *Infrastructures*. Created by some communities (C) to be used for coordination and value exchange utilising data. They implement some services (S) and are managed through governance (G).
3. *Services*. Created by/for communities tightly related Assets (C) and activated by specific infrastructures (I) and governances (G);
4. *Governances*. Created by/for communities to facilitate value exchange and structured in events and transactions (C). Services (S) and infrastructures (I) are implemented and regulated by governances.

3.3. The ecosystemic view of the economy

The knowledge-based view (KBV) to strategy and management highlights the role of knowledge and other intangibles such as network effects as drivers of the digital economy. Eisenhardt and Santos (2001) were among the first to contrast the knowledge-based view and the resource-based view (RBV). Efforts to account for intellectual capital and knowledge assets of firms are ongoing (Castro et al., 2013; Nadeem, Dumay & Massaro, 2019).

The changing nature of the EU economy and the availability of digital data introduce and require new approaches to analyze the economy to support policy-making. Therefore, we perceive major potential in investigating the EU ecosystem as a complex adaptive system (see Ritala & Phillips, *in press*) of interconnected agents.

A range of exploratory, descriptive, and predictive approaches from traditional statistical analyses to network science investigations on the relational structure of ecosystems (Basole et al., 2015; Järvi and Kortelainen, 2017). Moreover, both scholars and decision-making practitioners present visionary policy-making scenarios involving prescriptive analytical systems and human-AI collaboration. Examples include artificial sensing to support policy-making (Gross, 2017), the use of Smart Contracts to implement the "report once" principle (Sel et al., 2017), and the human-AI decision systems (Pentland, 2019). See also Larry Leifer's epiphany of human-robot collaboration (Ranftler, 2016) for inspiration.

We fully agree with Sturgeon (2013) and Gross (2017) that "data gaps lead to policy gaps." The quest to utilize the new digital sources of data, growing computational capability, and related methodology to support policy-making and related decision making is not new (cf., Still et al., 2012; Basole et al., 2015; Höchtl, Parycek, and Schöllhammer, 2015). In fact, the need to move from analog to digital indicators seems evident (Still et al., 2012). Yet, turning digital data traces and the promise of Big Data into dependable insights that can support decision-making and policy-making is anything but trivial (for a popular exploration of the topic, see e.g., Silver, 2012).

A review of novel research approaches conducted with the currently limited access to often poorly structured data provides insights on future possibilities to understand and visualize the EU economy as an ecosystem.

Measuring and visualizing the structure of business and innovation ecosystems is increasingly used as a method to conduct research (Basole et al., 2015; Russell et al., 2015). Structurally, a business ecosystem is analyzed as a network (Basole, 2020). Moreover, network analysis introduces a way to identify structural positions of actors to be used in, for example, statistical analysis on co-opetition preferences (Ritala & Hallikas, 2011). At micro level, structural analysis allows for the identification of individual actors for tailored action: observing companies in bridging roles or as hubs and connectors (for inspiration, see Smith et al. (2015) and Liu, Slotine, Barabási (2011)) - supporting, *e.g.*, the evaluation of actors for public financing instruments. The visualization of ecosystem structure has important applications also in (enacted) sensemaking (Bendoly & Clark, 2017) and ecosystem orchestration (Russell et al., 2011).

Table 4: Analog vs Digital (Still, Huhtamäki, Russell & Rubens, 2012)[46]

	Analog	*Digital*
Innovation	Companies R&D, closed innovation	Networks of companies, (eco)systems Open innovation, co-creation
	Few innovation actors	Many innovation actors, including users
	New technology	New technology, services, processes, and products
	Tangibles	Intangibles
	Waterfall-model of innovation	Agile innovation, lean start-ups
	Patents, scientific publications, Number of new products	Time-to-market, scalability
Data	Surveys, company reporting Lack of data	Digital footprints of innovation actors Information overload
	Structured data	Unstructured, unorganized, incomplete data
	Statistically representative samples	Biased data
Indicators	Lagging behind	Possibilities for real-time
	Manual processes	Economical computer-powered processes, though challenging
	Table format, some graphs	Interactive, data-driven visualizations, e.g., networks, timelines, ecosystem level

Financial system analysis in general and financial risk estimation, analysis, and management, in particular, receive a lot of interest from the research community. Soramäki et

[46] See tweet from @arhosuominen and a related book on science and technology indicators

al. (2007) modeled the network topology of interbank payments and found a tightly connected core of banks to which the other banks connect. Betza et al. (2014) presented an early-warning statistical model to predict individual bank distress. Soramäki, Cook (2016) developed a methodology to map multidimensional time series data into a two-dimensional space for quick insights on the temporal behavior of a financial system. For an example of ongoing European work on the topic, we point to Big Data Finance[47] that develops doctoral training on the use of big data in financial analysis.

Following the notion of the knowledge-based view, research has investigated the specific role of knowledge and intellectual capital in company performance. Intellectual capital is a combination of human capital, structural capital, and relational capital (Andriessen, 2004). Relational capital, for example, is the social capital counterpart to firms, taking stock of their relationships to customers, collaborators, and other entities (Still, Huhtamäki and Russell, 2013). Recent research seeks to develop means to account for intellectual capital (Nadeem, Dumay & Massaro, 2019). La Torre et al. (2018) concluded that big data is a new intellectual capital asset that will impact intellectual capital measurement and accounting. The notion of knowledge assets presents an alternative view to identifying the role of knowledge in company valuation, performance and success (Castro et al., 2013).

Simulation is seen to be particularly useful "in creative experimentation to produce novel theory" (Davis, Eisenhardt & Bingham, 2007). In studying managerial behavior and the outcomes of organizational action, simulation methods allow for the analysis of "multiple interdependent processes operating simultaneously" (Harrison et al., 2007). Alternative simulation approaches include system dynamics and agent-based modeling.

System dynamics is based on the study of combinations of feedback loops that together produce a certain outcome. Parker, Van Alstyne & Choudary (2016) point to a diagram that David Sacks drew on a napkin[48] to explain Uber's virtuous cycle that is based on network effects. A system dynamic model could be built from the diagram and used to test the interaction between these mechanisms with different parameters.

Agent-based modeling starts from agents that represent individual actors (Bonabeau, 2002). These agents are making rule-based decisions and are connected to each other through a (social) network. The models are used to study the behavior that emerges at the system level from these individual actors and their actions, given different variations and parametrization

[47] https://bigdatafinance.eu/
[48] https://twitter.com/davidsacks/status/475073311383105536

to the behavior rules and the network structure. Agent-based models can be either fully conceptual, that is, theory-based models that do not use data from the real world or hybrid combinations of theory-based properties and real life data (Huotari et al., 2017).

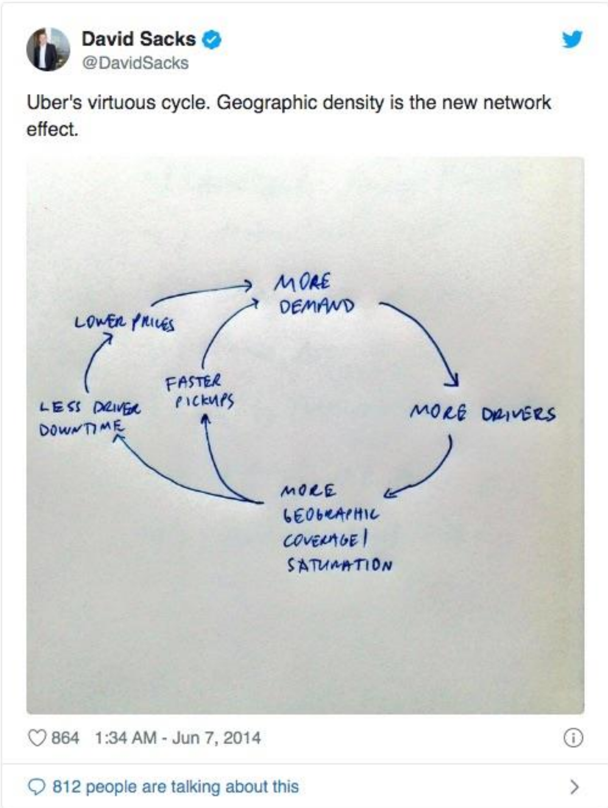

Figure 37: @davidsacks: “Uber's virtuous cycle”.[49]

Recently (or in fact in the very near future), Ritala and Philips (*in press*) presented a complex adaptive systems agenda for ecosystem research methodology, making connections between extant business, economic, and strategy research and the systemic view to ecosystems. This is an important contribution both for empirical and theoretical ecosystem research that has received critique for conceptual inconsistency (Oh et al., 2016; Ritala & Almpanopoulou, 2017).

In addition to academic activities, companies are already moving forward in developing commercial applications of the aforementioned scientific knowledge. Examples include Financial Network Analysis (https://fna.fi/), Teqmine (https://teqmine.com/), Silo.ai (https://silo.ai/), Palantir (https://www.palantir.com/), and Quid (https://quid.com/).

Why should the EU economy be modeled, analyzed, and visualized as an ecosystem exactly now and what kind of data? We subscribe to Gross (2017) that authorities are the main

[49] https://publish.twitter.com/?query=https%3A%2F%2Ftwitter.com%2FDavidSacks%2Fstatus%2F475073311383105536&widget=Tweet

architects of the contract-based data ecosystem that serves understanding and visualizing the EU economy as an ecosystem.

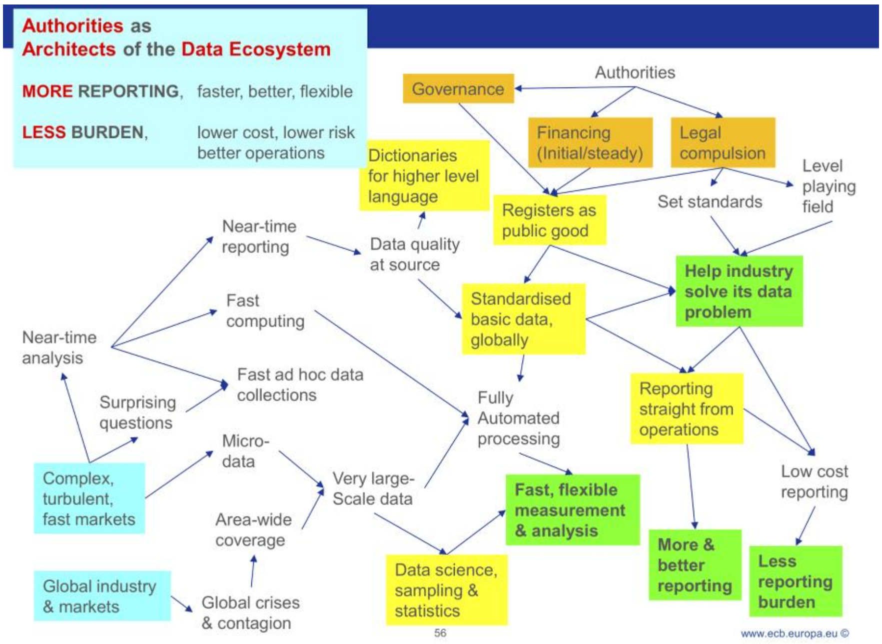

Figure 38: Authorities as Architects of the Data Ecosystem (Gross, 2017).

3.4. Data for modelling the EU economy as an ecosystem

Despite the hype around big data, digital data does not imply ease of analysis. The first obstacle in data analysis is *access*. Digital data is stored in a myriad of information systems from individual spreadsheets and relational databases to data lakes and platforms that span country boundaries. Invoices, transactions, information exchange, and other business activity is represented as bits with a plethora of data formats and vocabularies. *Data heterogeneity* introduces the second obstacle in its analysis. Small steps for data, giant leaps for the EU economy as an ecosystem include the introduction of the Legal Entity Identifier (LEI), “a 20-character, alpha-numeric code based on the ISO 17442 standard developed by the International Organization for Standardization (ISO).”[50] This also includes other initiatives by the EU such as the EU Open Data Portal[51] which makes available data like public tenders information, research project information, consolidated list of persons, groups and entities subject to EU financial sanctions etc.

Important examples of European efforts toward enforcing additional visibility and structure of business data include include the General Data Protection Regulation (GDPR) and the Payment Services Directive (PSD2). The GDPR enforces companies to explicate and make visible the contractual connections that are related to data collected from consumers.

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[50] https://www.gleif.org/en/about-lei/introducing-the-legal-entity-identifier-lei
[51] https://data.europa.eu/euodp/en/

That is, a company collecting data from consumers and passing it forward to other parties as a service must make these connections explicit and inform the consumer. The objective of the PSD2 is to open the European payment service market for competition by standardizing the means of accessing consumers' financial data and related functionality and by forcing banks and other financial institutions to enable the development of third-party applications. The PSD2 will ensure transparency and fair competition and break down the entry barriers for new payment services, which will benefit customers.

Other European examples include: e-invoices reporting in Italy, which will have to be issued through the 'Sistema di Intercambio' system ('SdI') for all local B2B and B2C supplies of goods and services using the 'Fattura PA' XML format. This will help the Italian Revenue Agency to automatically collect details of e-invoices which is the next step towards real-time reporting journey of the government. Estonian digital governance, which has created a convenient and flexible digital ecosystem connecting citizens with government and business entities, resulted in an unprecedented level of transparency in governance and built broad trust in its digital society.

In this era of platforms and APIs, data about API consumption and billing are spread across many systems that offer cloud solutions to companies with the objective to streamline their ecosystem and monetization capabilities. In this case, the contracts and the events are loosely coupled since those contracts are not computable and do not monitor in real time the execution of the service for compliance purposes.

The brief research review in the previous section shows that data already exists or is becoming available to conduct ambitious research on the ecosystem nature of the economy and the risks embedded in the current financial system. The data on contractual relationships between actors, both business-to-business and consumer-to-business, provides a potential starting point for understanding and visualizing the EU economy as an ecosystem.

Already today, deals and alliances data is at the core of the ecosystemic analysis of relationships between organizations (Schilling, 2009). For example, Basole et al. (2015) used the state-of-the-art deals and alliances such as Thomson-Reuters SDC Platinum to investigate the interconnections between key players in the mobile phone space. When contrasting the deals and alliances view with views, the importance of data triangulation becomes evident. **Error! Reference source not found.** shows the actors that are connected to either Google or Motorola Mobility. The prominence of Google is visible only in the executives and funding relationships view.

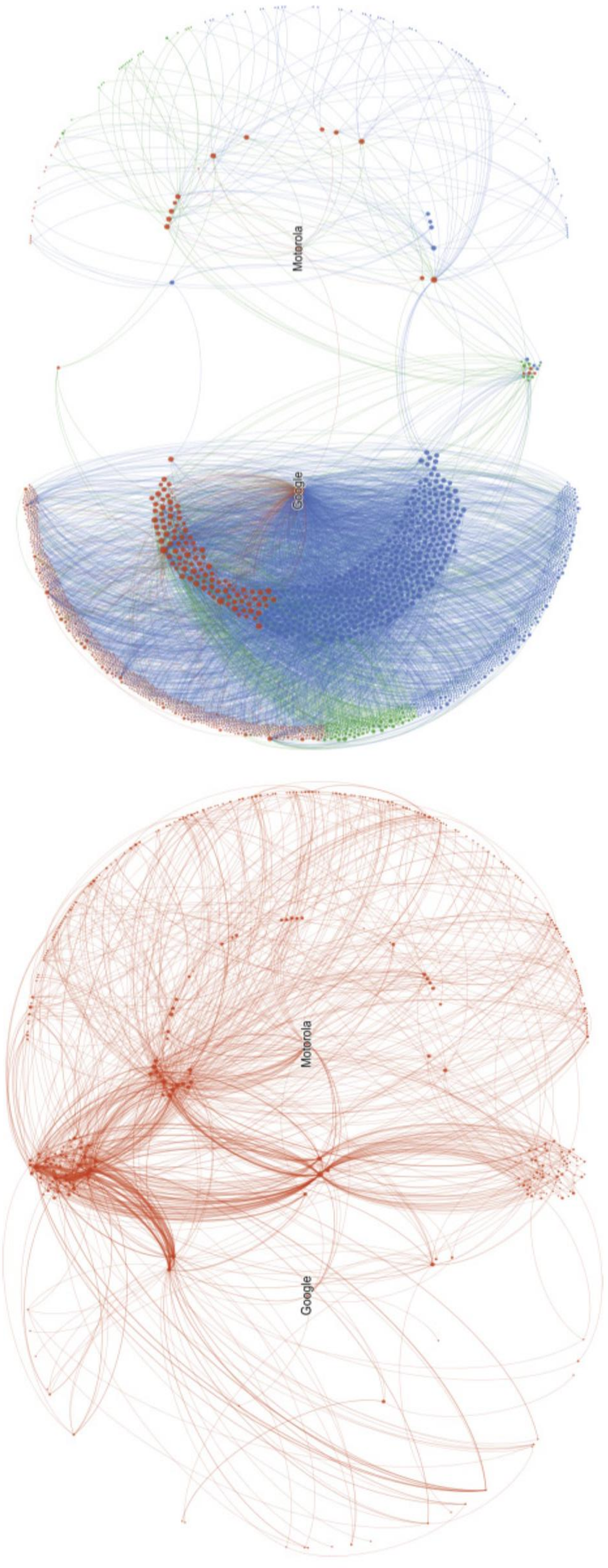

Figure 39: Two views of Google and Motorola Mobility ecosystem (Basole et al., 2015).[52]

[52] The left view presents the deals and alliances and the right view the executive and funding relationships within two steps of the two companies.

A quick review of an example of deals and alliances[53] brings up many issues with data representation. First, although a tabular representation is used, the individual partners involved with the alliance are enumerated *within* an individual cell. Already this is enough to stop a purely spreadsheet-based analysis exercise. Second, the timeline information is partly missing and dates are represented in non-standard format. Third, the vocabulary used to describe businesses (e.g., 'Mnfr integrated commun prod') seems inconsistent. Although an industry standard, the use of Standard Industrial Classification (SIC) codes has serious limitations in terms of specificity and spasticity.

In our proposed approach, both deals and alliances and executive and funding relationships are perceived and presented as smart legal contracts. As the example above indicates, the currently public contractual data, sourced for example from SEC filings, provides only a limited view of the economy as an ecosystem.

3.5. Transition to a Contract Ecosystem Modelling Approach

In a world increasingly dominated by digital platforms and machine-to-machine communication, the capability to master and analyse legal and compliance processes in real time is a necessity rather than a nice-to-have. The speed and velocity of economic cycles, though secured by current legal systems, suffers from the use of rigorous but slow legal practises and low-tech methods. The technology has run faster than the law; the original warning in Professor Lawrence Lessig's "Code is Law" is now a reality (Lessig 1999)[54].

In this context, challenges to legal systems and governance are growing as the world economy becomes more connected, global and automated, empowered by the usage of pervasive IT infrastructures and systems running global processes, executing services across national boundaries, transferring economic data and financial transactions. Although legal professionals are surrounded by digital information and software tools, the way they codify and represent contracts is still limited by old conventions and technologies that limit the possibility to represent digital knowledge and embed data, and to connect it to accounting principles and procedures.

Opaque and ineffective legal document practices are responsible for a very large part of the cost of doing business (Kahan & Klausner, 1997). Furthermore, the inefficiencies of current approaches create bottlenecks to economic and compliance processes, hides systemic risks and supports the trend toward data monopolies that are burdensome and dangerous.

[53] https://docs.google.com/spreadsheets/d/19KsbobAa7zvlsclmM0almom8tn0cZx7_NSbnzQHBKsM/
[54] https://www.harvardmagazine.com/2000/01/code-is-law-html

Traditional approaches to contracts are not fully-compatible with today's market speed and the virtualisation/tokenization of the economic system, trading and operational practices. Custom contracts in document form require too much human support, involve needless idiosyncratic variation and are totally disconnected from the way companies operate online. With the current wave of digitalisation and the reduction of companies' back office infrastructure, new alternative approaches are required to compete in such dynamic markets. This will not only cause a change in the way contracts are designed and implemented, but will also introduce contracts as dynamic organisms that can actively implement new business models, proactively manage relationships and assets, track obligations and dramatically reduce risk in transacting.

The history of contract automation over the roughly 60 years of the computational era is full of ironies and lost opportunities. Unfortunately, contracts are still a static element in a dynamic framework. Even in digital transacting, the terms of the contract (its semantics) are barely-structured "blobs": Word or PDF documents, or HTML pages. These are written and interpreted by humans and "translated" into application and payment management systems responsible for measuring transactions via APIs and automating the billing of such services to clients. Of course, both writing and interpretation are error-prone and the maintenance and coordination activities, even as between different departments of an enterprise are enormous. Furthermore, the reconciliation of contracts and transactions requires an additional level of analytical tools that makes the picture even more complex and expensive. The failure of structured systems such as SGML and the success of word processing led to needless complexity and massive "technical debt" in the field of contracting that is only now being addressed. This nearly universal failure in handling prose is paired with an even bigger failure in handling transaction data.

3.5.1. Idiosyncratic Enterprise Systems

The first computerized systems for transacting were back-office systems for banks and very large businesses. The software was written for core operations that justified the extremely high cost of computing. These systems originally had narrow, specific purposes and were often then expanded, patched, and made to communicate with other systems in the same organization and with others in a patchwork without ever really being rethought or recoded. They were, as the phrase goes, built like our cities "over time, without a plan, on ruins."[55]

[55] https://en.wikiquote.org/wiki/Ellen_Ullman

Critically, these systems failed to make a clear distinction between the records and the logic of the systems. A record or a part of a record had an idiosyncratic meaning tied to the system. A similar meaning would be expressed one way in one system and another way in another system. Technically speaking, there was a mixture of "state" and "model."[56] This resulted in extreme difficulty of improving the systems of banks and enterprise, and difficulties in making them interoperate. Their relationships – their ecosystem of contracts – are bound up in their specific systems of automation. One of the primary drivers of size of organizations has become the complexity of their IT systems. Smaller organizations have had significant disadvantages because of the cost of mastering systems.

3.5.2. Word Processing Dominated Legal Uses

The legal profession was also among the earliest trades to be automated, and it also took a wrong turn that has meant that much of the benefit of automation has been lost. It can even be argued that automation has made lawyers less efficient than before because lawyers now drown transactions in documents, expressed in Word and in its fossilised counterpart, PDF.

Legal and regulatory documents were one of the first intended uses of semantically structured text, in SGML, the precursor of XML.[57] But those early ambitions got lost in the marketplace. The first widespread system of legal document automation was minicomputer systems (notably Wang). With the arrival of networked computers, these ceded to WordPerfect. Microsoft Word supplanted WordPerfect as the change was made from DOS to Windows and the marketing power and global reach of Microsoft kicked in. The critical events happened, and the legal profession became committed to Word even before email and the Internet became part of the legal profession's toolkit.

Word became the nearly universal format for law, still mandatory for nearly all lawyers and others involved in contract drafting and negotiation, because contracting is very broadly networked. That is, a lawyer or negotiator will frequently collaborate with people that

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[56] The term "model" is also used in the programming paradigm of "MVC" - Model, View, Controller. Model provides the meaning, views are presentation to the users, and controllers make changes, https://en.wikipedia.org/wiki/Model–view–controller. The coordination problem of mixing "state" and records in enterprise systems could in theory be solved by strong leadership within the organization, but the actual ecosystem of software and suppliers is dispersed, often extending to suppliers whose motivations are not entirely aligned. The problem of "shared state" is perhaps best expressed in a piece relating to blockchains, Thomas, "The Subtle Tyranny of Blockchain
Re-learning old lessons about shared state," https://medium.com/@justmoon/the-subtle-tyranny-of-blockchain-91d98b8a3a65 2016

[57] SGML, the precursor of XML and other markup systems was invented at Bell Labs for legal and compliance uses, and the effort was led by a lawyer. https://en.wikipedia.org/wiki/Standard_Generalized_Markup_Language.

they have not dealt with before, with whom they will have to agree on a common format. Word became that format.

But Word was and is an inappropriate format. Word processing works by copying and reworking "full text" documents, in multiple drafts, even though most of contracting is a matter of some transaction-level modifications to an existing paradigm, incrementing an existing relationship. The use of word processing has resulted in extraordinary bloat of legal documents, to the point where it is functionally impossible to read all the documents that one consumes. In the era of typewriters, documents were short, fact-oriented, and generally more literate because they were usually the product of a team collaboration that included a highly-skilled secretary. Word processing removed the effort of making documents long, while retaining most of the effort of reading them. Game theory favored the proponent of long documents.

A penetrating exploration of the consequences of document bloat is given by Howard Darmstadter in his "Precision's Counterfeit, or the Problems of Complex Documents" (Darmstadter 2010).[58] Even very well-represented parties sign documents that nobody understands. It can even be said that sometimes nobody, not even the "author," has "read" the document because documents sometimes contain errors as gross as having the name of party from a prior use. A recent report in the New York Times claims that privacy policies are semantically nearly as complex as Emmanuel Kant's "Critique of Pure Reason."[59]

The length of legal documents invites treachery. A drafting party can hide unfair terms amongst the boilerplate, where it may go unnoticed or unappreciated.

The impact of document opacity is accentuated by the tendency of legal systems and courts to interpret the words of contract documents as if the parties had actually read them, understood them and intended them. This approach is particularly accentuated in the Anglo-American tradition. The precise words of a contract will often determine the outcome of a dispute even when one of the parties did not understand or read the terms.

3.5.3. The Alternative - Software Collaboration, Git

Meanwhile, the software community took a different path for text-handling. It developed tools and methods that are much more appropriate to the task of adapting text

[58] Darmstadter, "Precision's Counterfeit: The Failures of Complex Documents, and Some Suggested Remedies" 2010 https://www.jstor.org/stable/25758526?seq=1,

[59]https://www.nytimes.com/interactive/2019/06/12/opinion/facebook-google-privacy-policies.html?smid=nytcore-ios-share

solutions. This is likely due in large part to the fact that the software community knows how to make its own tools and to think systematically about information. But it is also true that they had little choice - the size of software projects routinely exceeds the size and complexity of legal documents by orders of magnitude.[60]

The core difference is that the software community uses plain text, an approach to documents that is radically simpler than Word, based upon open standards, and which can be edited with a broad variety of tools. They also make extensive use of modularity, breaking up text into components based on ideas. The software community "solved" the problem of collaboration via a reliable system of versioning called "git," invented by Torvalds, which is now at industrial scale on sites such as GitHub and GitLab.[61]

We intend to demonstrate that the modelling an ecosystem of contracts as a graph is largely a matter of borrowing from these very well-established practices of the open source software community.

3.6. Contracts as boundary objects

"Contracts" for purposes of modelling the European economy, includes much more than "contracts" in the legal sense. Much has been made of algorithmic substitutes for "law," and some even see algorithms replacing much of law and lawyering. The capabilities of mathematical and procedural expressions to handle transacting are already great, wide-spread and intermingled with conventional legal text and systems. For instance, in the case of the sell-side contracts, terms of service can specify dynamic resources via APIs (for example with the creation of Digital Rights Management to protect IP and control usage or Software-as-a-Service distribution models that are replacing Software licencing approaches) and operational models have been created to respond to this challenge. The same applies to e-commerce, where orders are transactions that customers program on the platform of the e-commerce host. Much of law has a cascading decision-tree structure that can and will be expressed algorithmically and by network representation. Computer-mediated transactions enable new forms of contracts and the records created by computers can allow the implementation of conditional logic that can be automatically monitored and verified, enabling more efficient transactions (Varian 2010). The benefits of computational contracts are therefore very clear

[60] This principle of necessity forcing better text handling is reflected in legal domains such as construction contracts. The set of documents and relationships are so complex that a conventional, word-processing-based approach cannot be effective. Systems such as FIDIC reflect this, using a system of cross-referencing by section name and number. Fidic.org. Financial swaps and derivatives have also given rise to systems of referencing www.isda.org.
[61] Torvalds, git, 2005 https://en.wikipedia.org/wiki/Git

for both economic, operational and compliance/risk perspectives. Standardise terms and templates, with minimal human touch, can increase deal velocity, decrease legal costs and even increment the monetisation of physical and digital assets.

As explained in the C.I.S.G. model, modelling relations is fundamental here, and there is a very intimate connection between the specifics of a transaction and the social context framed in a contract. To model the relevant relationships, we must consider contracts as boundary objects to include all relationships, transactions and steps in transactions that are documented in records, electronic or paper[62] (Suchman 2003). This broad definition of "contract" therefore includes:

1. Contracts in their great variety of subject matters, languages and jurisdictions.
2. Operations under contracts - including purchase orders, invoices, statements of work, payments, notices, change orders, confirmations and the like.
3. Events and transactions that have direct legal significance but are treated by legal systems outside of "contract law," such as permits, fines, litigation, co-ownership and family relations.
4. Finally, for having truly a picture of the social elements that underlie an economy, we must include records that have no direct legal significance, but which reflect network connections, such as attendance at meetings, location data and the like.

The unifying element is that these are all expressed as records. The records reflect social connections, what has been called "Social Physics" (Pentland 2015). Social Physics focuses on the connections and pathways of information flows. Information flows include transactions that are traditionally part of economic measures such as flows of money and goods, but critically, it also includes non-monetized transactions, relationships and even social proximity, as measured by interactions. This approach has been demonstrated to predict productivity, vulnerabilities and innovation better than conventional measures and certainly better than mere financial measures such as GDP. A variety of researchers, prominently including the Connection Science group at MIT[63] has demonstrated a number of technologies relating to the two critical features of a decentralised, secure data system - features which are in sharp tension with one another but are necessary to the effective functioning of an ecosystem: i) the sifting and analysis of masses of data to identify social patterns; and ii) the preservation of privacy and data security.

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[62] Contracts is broadly defined to include all document artifacts. Suchman "The Contract as Social Artifact" 2003, https://www.academia.edu/26702373/The_Contract_as_Social_Artifact

[63] www.socialphysics.org. See also footnote 1.

The first branch of Social Physics requires finding meaning in data - meaningful patterns among the mass of interactions. These techniques rely on machine learning, and have become very powerful. An example of this is a study that used mobile phone records to track the outbreak of disease.[64] Call patterns reveal changes in behaviors that precede and are much more detailed than formal reports. Social Physics is of course not unique in these analytical processes as we already mentioned, it is part of a huge upsurge in machine learning capabilities.

There is a tension between effective use of data and its misuse; data can also be a source of insecurity or oppression. Security breaches, social surveillance and social credit systems are examples of these dangers. These dangers echo conventional systems that totalitarian regimes used to oppress populations in Europe, but these new systems are potentially much more pervasive and powerful. There are many reasons to insist on data security, reflected in policies such as the GDPR[65].

This tension between use and misuse is difficult or impossible to control in a conventional model of data aggregation by platforms. The necessary complement to deep insight into data is proper partitioning, management, reduction and elimination. A really effective system of data security must be based on radically reducing the number of copies of data that are made, the number of places the data is replicated and the duration for which it is kept. Ideally, data would "rest in place," stay very near where it was generated, be kept under the control of the person to whom it relates, and be eliminated when no longer useful. Uses by persons beyond those immediate concerned would involve data reduction techniques, including summaries, "algorithm to the data" and analytics on encrypted data. Social Physics demonstrates a combination of technical and legal solutions that approach this ideal.

The key technical components are:

- Keeping data in encrypted form throughout its handling and transmission.
- Storing it with a primary "data fiduciary" who has legal responsibility to the data subjects or other producer of the data.[66]
- Having all interactions be based on secure queries of the primary data fiduciary, where the query originates from another, properly credentialed data fiduciary acting under verifiable authority of the data subjects.

[64] Project in the Ivory Coast done, with MIT Connection Science, Orange https://www.orange.com/en/Footer/Thematic-features/2013/D4D/challenge-Data-for-Development

[65] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32016R0679

[66] See Balkin and Zittrain, "A Grand Bargain to Make Tech Companies Trustworthy" 2016, https://www.theatlantic.com/technology/archive/2016/10/information-fiduciary/502346/

- Having all replies be minimum viable conclusions drawn from the data, not a copy of the data. (Called "algorithm to the data".)
- Contracts among data fiduciaries which require compliance, including data deletion, and corresponding contracts with the clients of the data fiduciaries - citizens, businesses and governments.

The technical components of such systems are available and have been deployed. An overview is provided in Trust::Data, (Hardjono 2016) as part of Social Physics. The EU's Payment Services Directive is driving adoption of "decentralised access management" systems based on similar ideas.

It can be argued that this approach cannot be as effective in drawing conclusions and providing guidance as those based on massive aggregation. But massive aggregations are in fact unnecessary in most settings:

- There is a declining marginal predictive value to greater aggregation of data.[67]
- Most decisions are highly sensitive to local facts: about the user, their history, network and immediate environment. Most things that people look for are similar to items that they have looked for previously and that other people nearby also look for.
- Encrypted algorithm-to-the-data can aggregate conclusions across data stores without sharing the actual data.[68]

The security of a partitioned data-management solution can also increase the amount of data that can safely be used, in the same way that a better set of brakes can improve safety at speed. In practice, a decentralized system of data management, connected with a trusted mechanism to control terms, access and monetisation of this data may be more effective than massive aggregations in generic even with respect to the quality of decisions.

A paradigm shift in technology and e-commerce is eliminating barriers, allowing transacting to be more secure and legal constructs more effective. This shift is arising from the digitalisation of information, availability and access to data, automation in decision making processes, expression of legal rules in code and the emergence of regulation by code. Since the end of the eighties with the advent of Cyberpunks and the Crypto "Anarchist" Movement[69], a group of computer scientists and cryptographers started analysing how to streamline financial transactions in a secure and eventually compliant framework. Between

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[67] "Data is subject to diminishing returns to scale." Is there a data barrier to Entry?, Hal Varian, Google. 2014 http://www.learconference2015.com/wp-content/uploads/2014/11/Varian-slides.pdf
[68] See, for instance data analytics on fully encrypted data. https://www.endor.com/
[69] https://www.activism.net/cypherpunk/crypto-anarchy.html

1995 and 1997 Ian Grigg and Gary Howland, with their Ricardo project, proposed an innovative method to "identify and describe issues of financial instruments as contract" (Grigg et al., 1997)[70]. The method offered two main contributions. First, it offered a way to represent provisions in human and machine readable format that could execute instructions automatically; and secondly, it provided a cryptographic approach where the parties would sign the document with private keys generating a unique hash that would uniquely identify the contract. This approach drew a lot of interest in the scientific and legal community, and enhanced the Smart Contract concept (Szabo, 1994)[71] that would only focus on the automated performance of the contract.

3.7. A General System of Contract Templating

In the "real" world, algorithmic transacting always is complemented by legal text. Unexpected things sometimes happen, an assumption may turn out to be false, a duty may be impossible to specify with precision, the "contract" may have a flaw, outside circumstances may make performance unjust or unjustified. In the vocabulary of Hart and Holmström, contracts are inherently "incomplete."

Terms of use, form contracts, rules of exchanges, consents, regulation and legislation provide a framework for the algorithmic elements. Legal language ascribes meaning, manages doubt, provides pathways for dispute resolution. The legal text forms a background for the transaction specifics and the algorithms.

Lawyers are trained to work the text that frames and enables transacting as "contracts" and similar documents. Technology trends put increasing focus on the importance of legal templates. Legal templates can be combined with code to offer a complete solution to automation of contracting, facilitate and leverage lawyers' work offering new and more effective building blocks to reconciliation, match and automate legal text.

New solutions are already in the market and legal tech providers like OpenLaw[72], Trakti[73], Clause[74], Monax[75] and others offer building blocks to use contract templates and execute contracts as smart contracts on blockchains. For example Trakti offers a full end to end unified platform for smart, executable and compliant contracts. Anyone in Trakti can

[70] Originally introduced in Ian Grigg, "Financial Cryptography in 7 Layers," 4th Conference on Financial Cryptography, Anguilla, 2000, Springer-Verlag LNCS 1962. All papers are at http://iang.org/papers/
[71] http://szabo.best.vwh.net/smart.contracts.html
[72] http://www.openlaw.io
[73] http://www.trakti.com
[74] http://www.clause.io
[75] http://www.monax.io

easily codify a legal contract in prose, can add parameters in markup language (that during the negotiation phase can capture input data, identities, real time data from third party systems) and can embed Smart Contracts to run on different blockchain infrastructures to enable the automated performance of the contract.

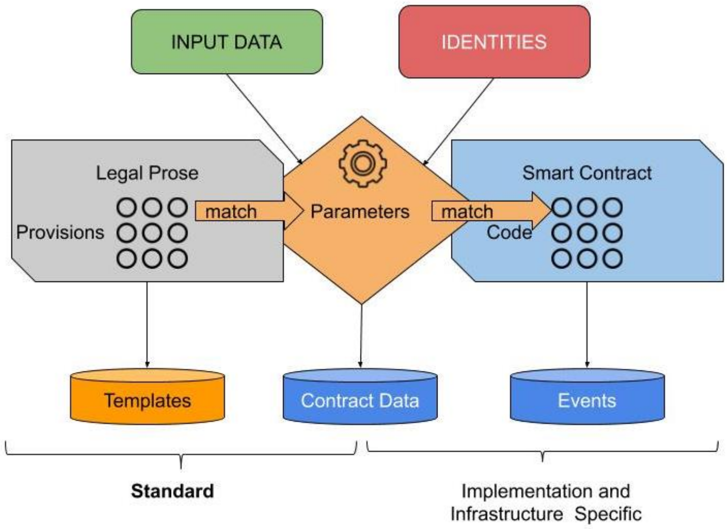

Figure 40: Connecting Legal Prose to Smart Contracts (Telesca, Hazard 2020).

Although very advanced and with a full set of functionalities that can facilitate lawyers work, each system has its idiosyncrasies, and each depends on standardising legal text.

To overcome those barriers and offer a common playing field to all those implementations that will facilitate lawyers' conceptualization and contract implementation strategy, we believe the clarity and certainty of legal arrangements can be radically increased by "codification" of legal documents in the legal sense.

Legal codification is perhaps the most ancient and effective legal method for increasing clarity, from Hammurabi and the Napoleonic Code to INCO terms. From "my" forms of businesses and agencies to model documents, industry standards and legislation, codification promotes clarity and stability. One attempt to use the internet to facilitate standardisation of contract clauses is the "Contract Wiki" project.[76]

We propose that these various forms of codification be integrated into a single system, as open source templates. The templates can be commented, rated and annotated like legal codes. They can also be adapted ("forked") and integrated ("merged") in a transparent process

[76] See Triantis "Improving Contract Quality: Modularity, Technology, and Innovation in Contract Design" 2013 https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2306209.

like software code. As demonstrated by the Open Source community the transparency and collaborative participation of developers in Open Source projects increase code transparency, facilitate the early identification of bugs, increase the level of security of the code, and facilitate innovation spreading. We believe the same can be applicable to legal code. Nearly all of the inefficiency, costs and opacity of forming and managing legal relationships can be eliminated by adopting text-handling practices that are already well-established in the Open Source software community. Software engineers have perfected these methods for their own use; business people and their advisors, including lawyers, can directly adopt and adapt them. Contracts can evolve to digital native models and become operationally active, managing relationships, supervising the provisioning of services and orchestrating transactions.

3.7.1. The Prose Object Model and the Open Trust Fabric

We envision a simple, general approach to unify all of these efforts around the shared necessity of legal text, a "Prose Object" data model for formalizing legal documents in a "graph" using standard tools from the internet. The approach can work with conventional legal document practices of word processing, with corporate systems of contract management and with blockchain systems of Smart Contracts. This is a way to express documents that is both familiar to legal systems and computable, to people and machines (Hazard & Haapio, 2017). It leverages the similarities among documents and relationships, even very complex documents and relationships.

An open ecosystem of documents enables standards to emerge from conventional legal negotiation, from the bottom-up practices, from the edge to the center. In Social Physics terms, this approach resembles the emergence of neural paths instantiating Kahneman's (2011) "fast thinking" from clusters of "slow thinking" pathways, or Herbert Simon's "action habits".[77]

In contrast to conventional approaches to standardization, this codification can be done in a decentralized fashion, natively during negotiation, by communities according to their own customs, or on larger scales as model document projects and formal legal codification. This openness, or "permissionless codification," is critical to capturing and reflecting the diversity of customs and uses, to retain the robustness arising from human diversity and to limit the suppression of differences and imposition of dominant models that characterize conventional codification and automation. The data model and collaboration method is profoundly open. Modification by "overriding" is available throughout drafting

[77] Social Physics, ibid, page 102 ("action habits"), Appendix 3 for "Fast, Slow, and Free Will."

and negotiation. Automation can also be entirely local. A person, company or community can "fork" an existing solution and use it locally. Conventional legal methods of document negotiation, the current ecosystem of contract competence, are supported and preserved, but made much more efficient and interoperable.

We point out a synergy between this diversity-preserving approach to codification and the problem of assuring that an automated system pursues appropriate goals. In strongest form that problem is the "existential" problem of artificial intelligence - how to assure that a machine will pursue human goals, even if it becomes more intelligent than humans. In "Human Compatible," Stuart Russell (2019), a leading researcher in AI, asserts that AI should incorporate doubt about stated objectives and persistently look to human choices for guidance. This embrace of doubt is parallel to the "incompleteness" of contracts. We suggest that contracts, formal arrangements among humans in complex, important matters, are a good source for finding human values via their most consequential choices.

The bottom-up activity should be complemented by traditional legal codification methods. There is a need for public-interest curation of templates for this new form of legal codification. There are a series of dangers to be avoided or managed relating to legal forms, including fraudulent or low-quality solutions; substantive domination by particular interest groups; and disenfranchisement of smaller communities and jurisdictions.

The new distributed transactioning platform will be expressed as a mathematical "graph." In computing and mathematics, a "graph" is a structure of "nodes and edges" (dots and connecting lines). Graphs are sometimes used in law, but have not had a common data format. Court cases have a well-developed system of cross-referencing in which each case is a node and the citations to precedents and legislation are edges. The ISO-LEI system of legal person identity and classification system is based on a "graph."[78]

Much of AI currently applied in law is used to transform unstructured information, such as agreements and related correspondence, into graph form. AI can also identify patterns in contracts expressed as structured objects in a graph. An agnostic system of AI pattern recognition could further accelerate the recognition of novel contributions from the edge.

The new distributed transacting platforms, such as the blockchain, would also reduce the cost of procedures both in terms of directly measurable costs (*e.g.*, legal fees) as well as opportunity cost in terms of length of procedures, reduction of risk, increasing transparency

[78] See the "graph" visualisation of LEI entities at https://correlaid.org/en/blog/hackathon-gleif/.

and overall performance of the European economy. As an example, having clear contract modelling structure and distributing transacting platforms would make it easier to interpolate production data generated by the implementation of those contracts and the impact on the data coming from the European Justice Scoreboard, offering a clear measure on how an efficient ecosystem of contracts could reduce operational barriers and sunk costs, to the benefit of European economies.

3.7.2. Fundamental Dimensions to analyse the EU as an Ecosystem of Contracts

This section highlights some of the “dimensions” of contracts. The proposed and tested Prose Object model, extends the work done in by CommonAccord[79] with infrastructural and data linking techniques and permits all "things" relevant to contracting to be expressed as objects in a graph.

It forms connections to the C.I.S.G. analysis. The primitives or graph “entities” in a contract graph include:

1. *Communities, Parties*: humans, legal entities, and “personas” (persons acting in a role, such as a bank account, web login or credit card) but also communities, in fact aggregates can also be expressed as objects in the graph, for instance groups of people (e.g. the employees of a company), or portfolios of contracts.
2. *Services, Assets*: both tangible and intangible, such as goods, digital or physical services, rights, social entitlements and shareholdings.
3. *Governance, Events*: connected to places, geographic coordinates, jurisdictions, postal addresses, events under contracts, sections of contracts, payments, deliveries, returns, confirmations and the like.
4. *Infrastructure, Data*: such as physical, digital (embedded, cloud, blockchain), Smart contract code, data sources, (coming from sensors, GIS and logistic platforms, ticketing and project management systems, third parties software), connected to performance metrics that could feed the ERPs and accounting systems of companies, contextual data like weather forecast, SLAs, KPIs, all those connected to events under contracts, parameters and the like.
5. *Patterns*: prototypes for contracts, including model documents, sections, phrases, presentations, connections to infrastructures, code implementations and database queries.

[79] http://www.commonaccord.org/

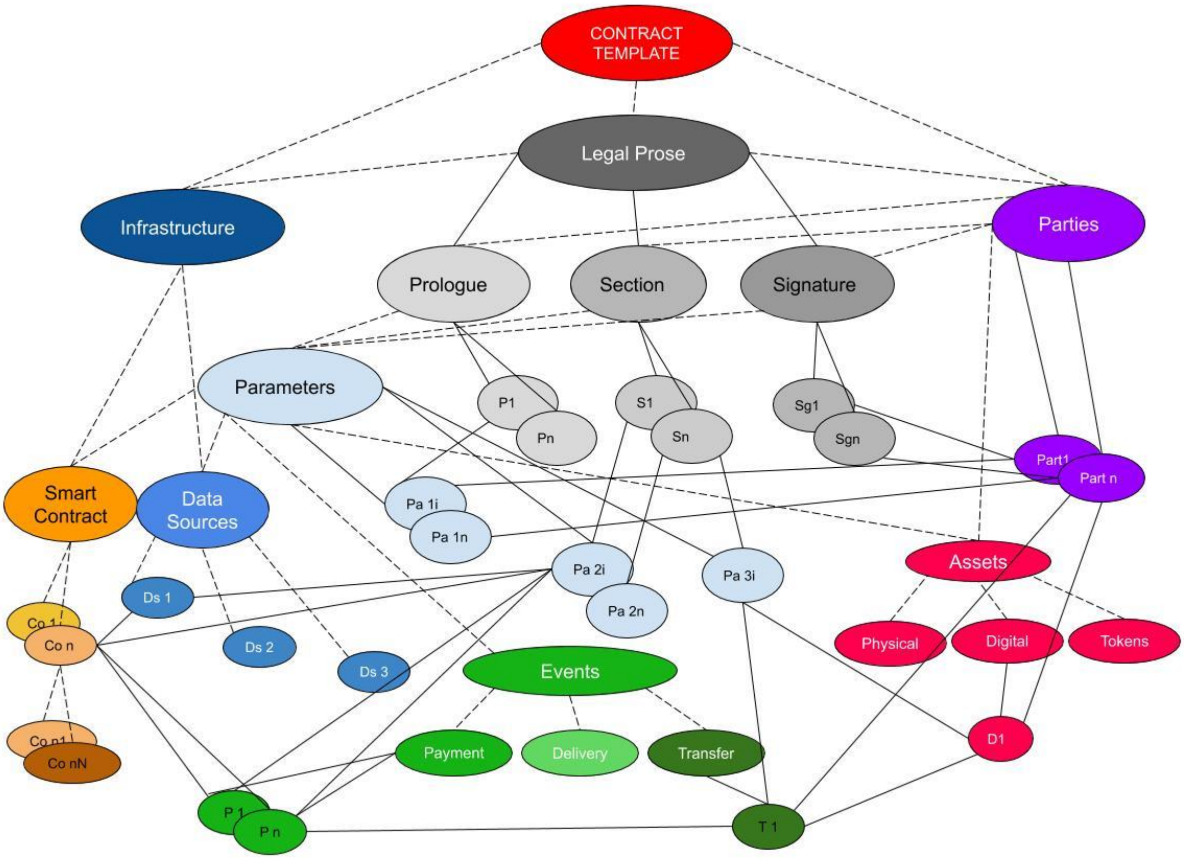

Figure 41: The Prose Object Model (Telesca & Hazard, 2020).

There is a strong similarity between the Prose Object "graph" organisation and the "semantic web" models that have long been advocated by the W3C and Tim Berners-Lee. The W3C and Berners-Lee quite rightly insist on the radical leap in usefulness that semantically organised and marked text can achieve.[80] Those efforts have suffered, however, from a dependence on top-down standardisation of the semantic vocabulary, the taxonomy or "schema."[81]

Prose Objects innovate on the W3C approach by avoiding any top-down naming requirements. The semantic model is based on managing documents as sources rather than post-hoc tagging of document blobs.[82] The use of "prototype-based" inheritance locks the system open.[83] A person can start with any existing solution and adapt it without restriction, or a community can also start on their own, completely new, using only the basic record paradigm, and still expect that interoperability can be largely achieved if desired. In this

[80] https://en.wikipedia.org/wiki/Semantic_Web
[81] https://schema.org/
[82] See, for instance the "xray" view of any document at CommonAccord.org http://www.commonaccord.org/index.php?action=xray&file=G/Lykke-QuickSwissConsultAgt-CmA/Demo/Acme-Ang.md
[83] Prototype-based Programming - https://en.wikipedia.org/wiki/Prototype-based_programming

respect Prose Objects resemble “git”, which has demonstrated the power of a common format for sharing files. In computer science terms, Prose Objects have no mandatory “classes,” and no mandatory “schema.” The only “type” is the record format, and even that is “abstract” - expressible in a number of formats, including flat files, JSON, XML and databases.[84]

Each object in the graph can also have properties inherited as classes. For instance, a person may be a human, with a gender, and one or more citizenships, or may be a corporation, partnership or other type of legal person, with a jurisdiction of organisation. The system can both express contracts that reflect these properties, for instance a contract by a legal person must be signed by another (human) person, and with pattern-recognition software, can reason based on these properties (a contract signed by a minor might be invalid or illegal). Another example can be the assurance of security and uptime for data hosting. For instance, in a first step, the manufacturer of networking equipment could have a playbook of clauses for performance assurances, what are sometimes expressed at "service level agreements" or as warranties. That playbook could be published as modules in a public forum, for instance on GitHub.

In a second step, those clauses could be used between the equipment manufacturer and a telecoms company, becoming part of the contract between them by referencing the clause identifiers and completing any parameters. In a third step, the telecoms company could extend the same assurances to the telecoms customer, for instance a bank, again by referencing the public identifiers of the clauses, and overriding only those elements that need modification. This would assure conformity of legal obligations across the chain. In a fourth step, the parameters could also feed a smart contract that was tied to performance monitor "oracles." In the event of any failure, the smart contract could alert the appropriate parties and establish a credit for the customer. These could also feed a dashboard for systems monitoring.

3.7.3. Contract Codification, Graph Expression and examples

As anticipated in the previous sections, contracts and legal procedures should become smart, adaptive, reactive and proactive, and their direct contribution, in terms of process improvement, should become more clear and measurable, not only during the formation of the agreement but also during its execution. Contracts should reduce risks, make risks more visible, and make dispute resolution (including litigation) more rapid, predictable, fair and

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[84] The flat file format, developed by Primavera De Filippi, is used for collaboration on GitHub.com. See. github.com/CommonAccord. A JSON version was developed by students at Brown University https://github.com/adonalsium/common_accord/tree/dev.

efficient, both in terms of costs (including legal fees) as well as opportunity cost in terms of length of procedures.

There are many ways to standardize legal text. Legislation is the most centralized, and also the least agile, most reductive and most subject to lobbying and insider trading. Regulation is similarly centralized, though a bit more agile and able to adapt to complexity. Rules of exchanges are legislation as among a community. Terms of use are centralized by a business. Government and court forms are centralized by an agency. Model documents are quasi-standards for a community. Law firm forms are also quasi-standards, though tied with services and usually masked with a tilt in favor of the client's party. Corporate form documents are standards that are usually masked with a strong tilt, but also harmonizing the company’s relationships.

Despite the existence of many islands, a vast dispersed archipelago of standardization, no general process of standardization of legal documents exists, connecting these islands. There are some efforts with broad ambition, such as standard processes and tagging of legislation, but none have a comprehensive ambition or the do-it-yourself, go-your-own-way, iterative dynamic of open source software. The major reason for this is simple and perhaps surprising: until now, standards have been very largely developed, maintained and published using conventional word processing technologies.

Legal standards are transitioning to Internet platforms that allow much more effective collaboration and publishing. As we already analysed, this trend is being accelerated by numerous smart contract and legal template projects, so-called “Ricardian contract” approaches. CommonAccord.org demonstrates a generalized approach to legal document standardization that is compatible with those approaches and with conventional legal document processes. It transposes the collaboration methods of open source software to the legal setting. Convergence on these standards graph templates can be greatly accelerated by Artifical Intelligence (AI) / Natural Language Processing (NLP) technologies that identify patterns and common denominators in legal documents. Business pressures also drive standardization. As a practical matter, it is very difficult for a business to manage transactions and relationships if the legal terms of multiple relationships are idiosyncratic, one-offs. Therefore we consider the need of an Open Trust Fabric of identifiable, community endorsed contract template graphs, which can be accessible in an open innovative repository based on a set of community-driven Web tools to promote the vision of available contract ecosystem "as a living organism." Ideally, the efficiency will be realized from grass-roots use (technically, the “edge”). That is one of the advantages of focusing on tools that let people write and manage conventional contract documents more efficiently. This approach is focused on the "parameters" and "prose" elements of "Ricardian Contracts".

A complete system of standards-based transacting based on Open Trust Fabric requires the following elements:

1. Open source libraries of contract Prose Objects organized in modules.
2. Open source libraries of contract Code.
3. A method for unique contract identification to be connected to LEIs, Legal Entity Identification standard (20 digit code based on ISO standard), infrastructures and transaction IDs.
4. Open system of peer-to-peer identification, authentication and access control across infrastructures.
5. A method for querying and analyzing data that minimizes data copying or pooling.
6. A network of connected infrastructures and hosts for transaction data, open to properly credentialed and compliant candidates.
7. Framework agreements defining the rights and duties among the hosts and with participants.
8. Supporting regulation.

When organized in a "graph" model, these enable a high-performance, secure approach to transacting that has the properties described as "Social Physics." We call it an "Open Trust Fabric Alliance".

The elements of the graphs will be organized in a multi-dimensional way, without any limit on the number of dimensions. Some necessary dimensions include:

- **By Industry or Community**
  - Different industries, and communities have different customs, even when doing the same kind of contract. There are numerous industry-based standards, some of which are formalized in standards organizations and some of which are reflected only in law firm "practice areas." At a most-general level:
    - Food and Beverage.
    - Manufacturing.
    - Real estate.
    - Logistics.
    - Finance.
    - Health.

        - Information Technology.
        - Energy.
        - Education.
        - Government.
        - Crypto.
- **By contract type.**
    - This includes commercial, consumer and administrative. For instance, at a very general level:
        - Sale.
        - Lease.
        - Loan.
        - License - particularly relevant - see below.
        - As a Service.
        - Co-ownership - e.g. corporate or partnership.
        - Permits.
        - Credentials.
        - Litigation .
- **By infrastructure and format:**
    - Off-line:
        - Paper.
        - Word.
        - PDF.
    - On-line:
        - Cloud:
            - Word.
            - PDF.
            - HTML.
            - Git.
        - Blockchain:
            - HTML.
            - Git.
            - Smart Contracts.
- **By document type:**
    - Binder of Related Contracts
    - Contract.
    - Statement of Work Purchase Order, Receipt, Consent.

    - Sections of a form agreement, including definitions.
    - Parameters, descriptions and tweaks for an actual contract.
    - Code.
- **By language or jurisdiction:**
    - All European languages and Jurisdictions.
- **By phase of the contract:**
    - Templating.
    - Signed.
    - Live.
    - Completed.
    - Deleted.

There are many other dimensions we did not list here that could facilitate the categorisation and identification of types of contracts that we expect a repository should be able to cover to facilitate, during the set-up of a relation and all the related objects (parties, events, transactions) that will take form. To facilitate the identification of transactions and reconciliation a unique ID has to be defined for each contract type that will emerge in the repository and that we believe should be connected to each transaction ID. To explain in concrete how contract graph works we decided to consider two relevant examples: licenses and privacy consents.

3.7.3.1. Licences

Licenses provide rights and access to intellectual property, data and the like.

- License agreements vary in many respects, including:
    - Subject matter - Patent, Copyright, Trademarks, Trade Names, designs, data collections, and combinations of these rights.
    - Within each category there are vast variations, including whether the license is exclusive or non-exclusive, short or long term, revocable or irrevocable, fee-bearing or free, supported or not, sublicensable, etc.
    - Licenses are written in all languages, and subject to all jurisdictions.
    - Localities and industries have customs and individual actors have preferences. Circumstances are as varied as life.
- But license agreements also demonstrate strong similarities:
    - They have parties - a licensor and licensee, perhaps an escrow agent, auditor, sublicensee, master licensor, beneficiary.
    - There is a grant and some limits, in time, scope, geography and the like.

- The parties make assumptions about one another, which can be formalized in representations and conditions, or disclaimed.
- Disputes may arise and need a method of resolution.
- We demonstrate a model for the codification of all license agreements, using an "object-oriented" approach where:
    - A language-agnostic agreement frame -> an English-language frame -> a taxonomy for licenses -> a software licence type -> specific text and specific parties.[85]

3.7.3.2. Consent

A second, related example is the field of "consents" to information usage. Consents are, very abstractly, a kind of license document. These are particularly important in connection with the GDPR, but they are pervasive. Consents are used in connection with many kinds of operations, they document and create obligations that are complex, contextually bound, bilateral, often strung together into information supply chains, and sometimes quite long-lived with continuing obligations to the original data subject. These chains often connect using data sharing agreements and similar licenses. They are particularly relevant to understanding the social and trust relationships in an ecosystem, the Social Physics.

- Current systems of consents are notoriously inefficient. The citizen or consumer is confronted with a complex text, about a field that is both complex and changing and about which they have little competence or interest, and over which they usually have little or no ability to negotiate. The GDPR compels improvements in this, but also makes click-through even more pervasive and meaningless than before.
- A better GDPR-effectuating solution would be based on standards and reputation (Social Physics). The taxonomy would be shared, the text would be sourced from shared materials, it would be rated and subject to commentary by experts and peers.
- We demonstrate this in connection with both the GDPR[86] and a system created by the Global Alliance for Genomics and Health.[87]

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[85] See - the demo of a "universal" license taxonomy instantiated with some specific parties and a complete set of confidentiality provisions. http://www.commonaccord.org/index.php?action=doc&file=G/Agt-License/Demo/SoftwareOutline-WithFullConfidentialityText.md

[86] A privacy policy based directly as pass-through of GDPR and Kantara taxonomy. Click "Document" to see the whole. http://www.commonaccord.org/index.php?action=source&file=G/EU-GDPR-Law-CmA/Demo/Acme_UK.md

[87] Global Alliance for Genomics and Health, model consent and object model http://www.commonaccord.org/index.php?action=list&file=Wx/org/genomicsandhealth/REWG/Demo/

- Another example of this work is the Kantara Initiative project to create a comprehensive Consent Receipt that is compliant with the GDPR, and compatible with API-based secure authentication and data-minimizing access.

3.8. Blockchain, Smart Contracts and the Rule of Law

As we already mentioned Open Source and standards can keep the Open Trust Fabric system honest by radically reducing the cost of replicating the system, of defecting from the group or of attacking its privileges from outside.

Therefore, a principle impact of the blockchain may be to promote the open-sourcing of standards for code and legal templates. In Ricardian contract vocabulary, "code" and "prose" will replace the current system of incompatible automation systems and word-processing ping-pong, as well as opaque, take-it -or-leave-it merchant-imposed contracts-of-adhesion. The code and prose will be able to run on blockchains, but also on conventional platforms, within enterprises and among them.[88]

An additional pressure for standards comes from the GDPR and from the Payment Services Directive. These require, directly and indirectly, a transacting platform that enables compatibility, API-based transacting and data minimization.

3.8.1. Social Physics Data Minimisation - Data at Rest

Effective data minimization requires that data largely "stay at rest," that is, data about a contract (or any other matter) ideally is available only to the parties themselves and to persons that they deem necessary to be informed or to act as hosts. There must also be a method for eliminating data that is no longer needed, while providing a guarantee against fraudulent assertions about the data after the destruction.

Taking these together, these point to an approach to data management that can be described as truly decentralized. Strong rule of law, whether directly from regulatory supervision or from a framework agreement, permits a truly decentralized approach that combines data minimization with strong effectiveness. The technologies for these systems are already available and being implemented, particularly in Europe where the PSD and GDPR are driving API-based systems.

[88] Indeed, for practical use, code and prose must be able to run on private systems, independent of blockchains. Organizations have much higher needs for rapid response and querying of their transactions and history than blockchains permit, and extensive existing automation systems, both for transacting and for operations.

3.8.2. Role of Core Actors and Institutions in the Open Trust Fabric

There is a danger in decision-making of what can be called premature optimization - finding a solution and then reinforcing it. This notion can also be understood as local maxima. It can be said to be the core problem explaining both the technical debt of financial institutions and of the legal profession. Overcoming such premature optimization is difficult because of network effects (Kuhn 1962).

This problem is particularly dangerous in the current context, when designing an automated system of reporting and transacting that is intended to work across cultures and legal systems, for the benefit of the users and not the benefit of the creators or maintainers of the system. It is too easy for a solution to develop premature network benefits that cannot be overcome, and end up imposing solutions that are ill-adapted and not democratically legitimate. In Social Physics, they demonstrate that feedback from like-minded people can reinforce groupthink and result in sub-optimal results and even bubbles.[89] In our own context, the dominance of incumbent platforms can be understood as premature optimization.

Similarly, conventional rule-making suffers from a centralisation problem. Conventional rulemaking - whether as legislation, agency regulations, market rules, model documents, even "our" corporate form - depends on small groups of experts, usually with inadequate diversity of experience and views, to do their best for the entire community. There are conventional checks and limits on this that help somewhat. For instance, decision power can be distributed across branches of government, and across governments in subsidiarity, federalism, local government and the like. But even these systems still involve high degrees of centralisation, with the attendant reductivism, myopia and lobbying, even if they are multilayered.

To combat this, it is important to have a system of Social Physics that can be used "from the edge" - by local actors pursuing their own objectives independently of any agenda or participation by the "center." In an ecosystem of contracts, this can be done by leveraging the device that the edge (businesses and citizens) currently uses to define relationships: contract documents. Most contracts, meaning here formal legal documents, are currently negotiated locally, among the direct participants or their advisors. This is true for "contracts" in the private sector and is also very substantially true for the vast variety of forms and official documents used in local, regional and national governments. A team creates a document which is intended to define the relationship.

[89] Social Physics, ibid, page 37.

This vast ecosystem of documents and authors expresses a highly nuanced picture of relationships across the economy. But it is profoundly inefficient because expressed in word processing, as a practical matter, in “Word”, a proprietary and vastly complex document format, or in “PDF”, another proprietary format. The same ideas are expressed and renegotiated over and over in needlessly varying iterations, and the results are semantically unstructured. These documents are very difficult to use in management and reporting,[90] and the varying language is subject to endless arguments about interpretation, even regarding the most common ideas.

In the same way that data and security can be reconciled with Social Physics, so can local expertise and preference be reconciled with efficiency and interoperability using Prose Objects. This can be done by retaining the conventional form of legal documents while enabling each author to leverage common materials in the way that Torvalds and others showed how to collaborate on code. Those concepts are core in the suggested “Open Trust Fabric” distributed architecture approach.

There are many other poles of activity for improvement of transacting, the law, and modelling. These notably include standards groups, trade groups, legal improvement groups and the broader open source movement. We highlight only a few of these - the IACCM, UNIDROIT, the European Law Institute, and expect to confederate them as part of the Open Trust Fabric open distributed infrastructure.

The types of actors needed to create and operate a system like this can be organized by the kind of trust that individuals, businesses and governments place in them. Articulated as “fiduciaries, we can group these as four types:

1. **Pattern Fiduciaries:** coders, lawyers, designers and others who define paradigms.
2. **Data Fiduciaries:** person entrusted with data. Banks, Fintechs and other payments processors are likely to be on the front line because they already perform this role, have bank secrecy obligations, and are regulated at various levels. Other prominent data fiduciaries include telcos, health authorities and governments.
3. **Decision Fiduciaries:** advisors, conservators, agencies, courts, regulators, governments, legislatures
4. **Infrastructure Fiduciaries:** telcos, blockchain ecosystems, logistics, on demand manufacturers, food preparers, etc.

[90] See, for instance, the vast array of technology solutions that attempt to extract meaning from collections of contracts - https://software.iaccm.com/

3.9. Managing Contract Ecosystem Analytics

In this section, we turn our attention to the following question:

Which existing data sources, data collection methods, data methodologies are available to model the EU economy as an ecosystem of (legally enforceable) contractual relationships?

Inherently, the digital economy transforms economic activity into data.

We review the ways to manage ecosystem analytics at two complementary levels of abstraction, the analytics process and the technical system architecture.

3.9.1. Analytics Process and System Architecture

The business intelligence firm Houston Analytics presented an interesting conceptual process model for developing and conducting data analytics to support and implement decision-making. Their model is an extension of cross-industry standard process for data mining often referred to as CRISP-DM (Chapman et al., 2000).

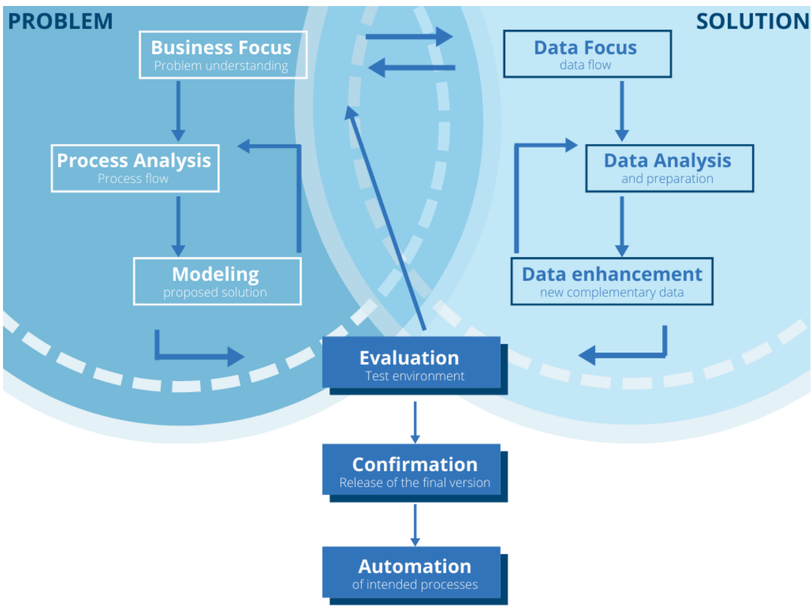

Figure 42. Process for developing and conducting data analytics.

The Ostinato Model (Huhtamäki et al., 2015) is a process model that identifies the individual processing steps and their interconnections for implementing data-driven visual network analytics systems. This process is divided into two macro phases - (i) Data collection and refinement; and (ii) Network construction and analysis.

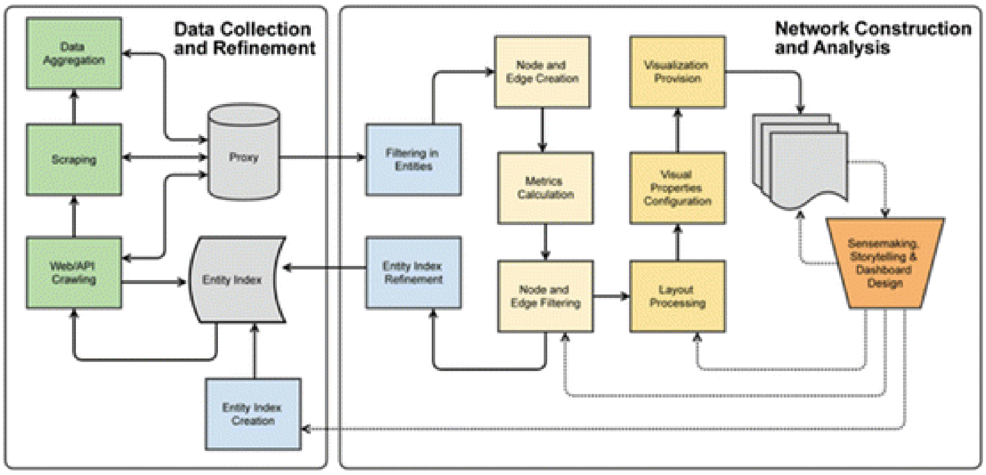

Figure 43: The Ostinato Model (Huhtamäki et al., 2015).

The general rules of data-driven analytics apply in implementing the Ostinato model: collecting and cleaning the data will, in most investigations, consume most of the time and resources available for the investigation. But in our proposed repository and metadata based approach data is not very scattered but its already connected with the contract, as a result we might not need to do for scrapping but we may need to connect with different API to collect data. To be specific, in data collection and refinement phase contract metadata is collected from the repository of contract template, contract data from contract and execution logs from the blockchain. This phase also refines the data for analysis and visualization purpose.

Table 5: Enumeration of the main network entities and their ecosystem counterparts

Network entity	Ecosystem feature
Nodes	Actors and only actors (or actors and actants as in Actor-Network Theory)
Edges	Contracts (and anything related, including transactions)
Edge weight	Intensity of transactions (e.g., money exchanged)
Edge direction	the type or relation and information flow (symmetrical, asymmetrical, indirect, direct)

Network construction and analysis phase all refined data is aggregated, transformed and linked to represent using a graph. Once the desired metrics are identified it can be calculated during the metrics calculation phase which will lead to filtering of the nodes and edges of the graph.

Although in principle, every metric can be calculated from the graph, in practice it may not be feasible for the reason of efficiency. Visually different types of nodes can be represented with different size, color, border and shapes whereas different types of edges can be represented using different color and width.

3.9.2. Analytics System Architecture

In the context of digital contract ecosystem, one feature sets the scene for analytics system architecture. That is, the implementation is based on blockchain. From analytics system viewpoint, blockchain shares features of peer-2-peer systems. Importantly, there is no central database or other single source of data for the analytics system (Nykänen et al., 2008). However, in order to facilitate the development of applications in general and analytics applications specifically we can describe the Blockchain application architecture in the following way (see Figure 44).

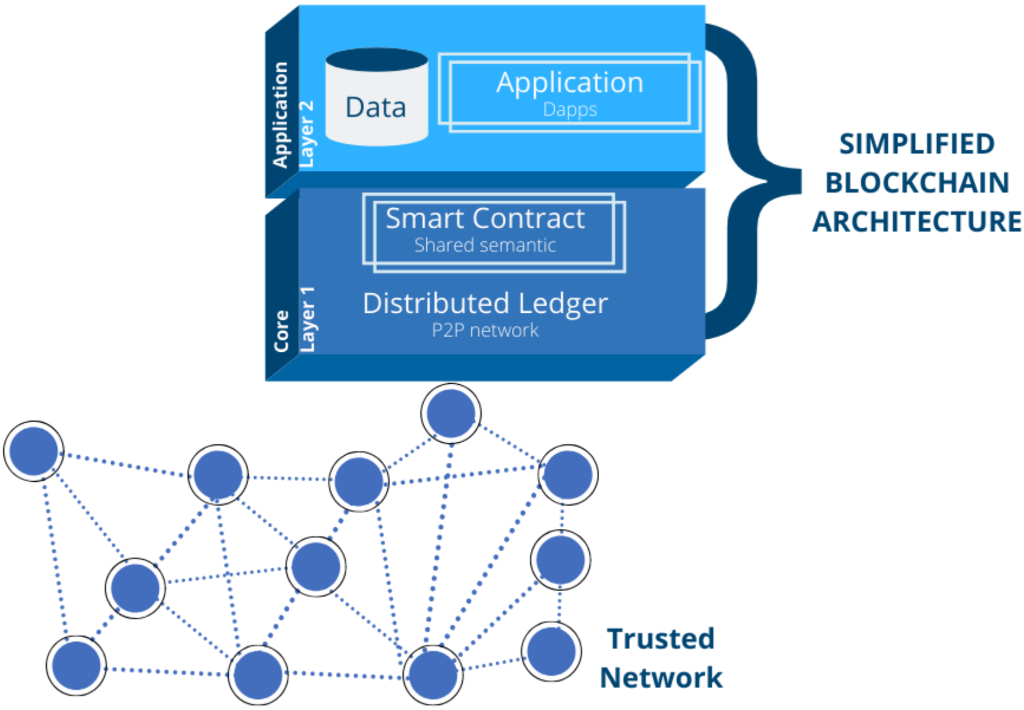

Figure 44: Application layer operates on top of the Blockchain layer and the underlying Blockchain network

In Figure 45, we give the application developer an even more familiar context. The developer accesses the data and system functionality through an application programming interface that hides the details of the underlying technology and its potential complexity. Importantly, the Shared Data Ledger only includes references to the auxiliary databases that are then queried for big data and private data.

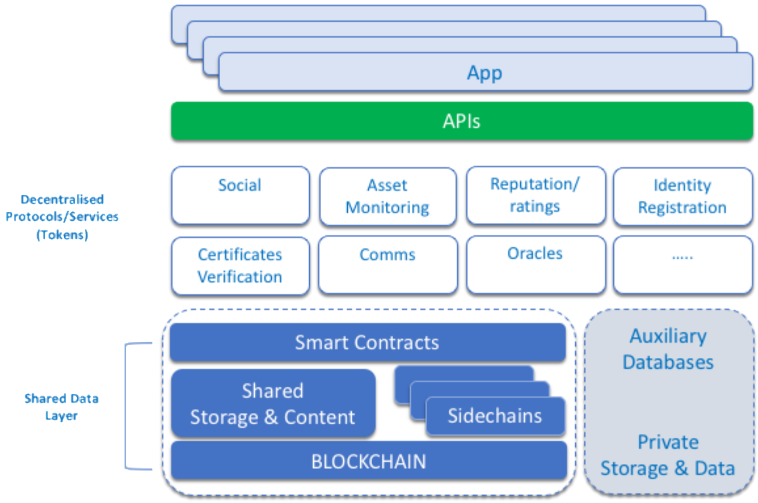

Figure 45: Applications access the Blockchain and auxiliary databases through APIs.

EthViewer.live (http://ethviewer.live/) is an example of a Web-based visualization application that operates in real-time. The visualization interface is implemented with D3.js, a Javascript library for developing Data-Driven Documents - hence the name. The data is streamed from a backend streaming API using Socket.io, a popular JavaScript library in implementing real-time, bidirectional and event-based applications. The implementation technology is not known or even relevant, thanks to the Web API-based design. However, we expect that the backend is implemented in Node.js, the de facto technology for asynchronous and real-time Web applications. D3.js is an expressive approach to implement interactive visualizations. However, there is a steep learning curve. Fortunately, D3.js comes with a variety of example visualizations in open source that can be used for prototyping and ramping up development.

Figure 46: Excerpt of D3.js example visualizations available at github.com/d3/d3/wiki/Gallery.[91]

[91] Courtesly https://github.com/d3/d3/blob/master/LICENSE

Alternative Web-based visualization implementation technologies include easily configurable and expressive Highcharts (not open source) and GEXF.js[92] for interactive network visualizations. Visualization tools are also available as a service. Network-specific examples include Kumu.io and Ecoxight[93] (Basole et al., 2018).

Importantly, an analytics system can take many forms in addition to the Web-based implementation. In fact, the Web-based dashboard systems are a specific and popular case of analytics.

Traditional statistical analysis continues to be implemented with tools including SPSS and Excel. Structural Equation Modeling insists on the use of tools such as AMOS. These approaches usually operate on spreadsheet data in CSV.

Data science is usually associated with a coding approach. The main two communities use either R or Python, and an ensemble of related modules and software libraries, including Pandas and scikit-learn. Here, the spreadsheet data is complemented with JSON datasets, databases, and API programming.

Financial analysis is an example of a data-intensive activity that insists on high performance computing environments, including Apache Spark (Stockinger et al., 2019). Computing clusters and related data management practices come into play here.

Simulation comes with a set of dedicated tools, including AnyLogic providing high levels of abstraction. Due to their computing-intensity nature, simulation models are currently able to consume a limited amount of data.

The field of business intelligence is moving forward fast and keeps introducing new tools that are developed with the non-technical analyst in mind. Examples of interesting business intelligence tools include Tableau[94], Qlik Sense[95], and Power BI[96]. Alteryx[97] and Trifacta[98] are among the data-cleaning and fusing tools used to increase to the quality of the data.

[92] http://www.rshiggins.net/gefx-tutorial.html
[93] https://ecoxight.com/
[94] https://www.tableau.com/
[95] https://www.qlik.com/us/products/qlik-sense
[96] https://powerbi.microsoft.com/
[97] https://www.alteryx.com/
[98] https://www.trifacta.com/

3.10. Prerequisites for Analysis Supporting Policy-Making

Three prerequisites for the use of the Open Trust Fabric as source data for analysis supporting policy making: access to data, access methods and structured data.

3.10.1. Access to data

Computational social science is an emerging research field that utilizes the new digital sources of data for creating insights into the behavior of individuals, groups, and organizations (Lazer et al., 2009; Cioffi-Revilla, 2010). Social physics (Pentland, 2015) is a particularly ambitious approach to computational social science, claiming to analyze data for identifying mechanism of human behavior similar to the laws of physics. Others, including Watts (2013) agree on the potential of analyzing the digital traces for insights on the behavior of humans and organizations. **Watts (2013) introduces the notion of *social supercolliders*, "a facility that combines multiple streams of data, creating richer and more realistic portraits of individual behavior and identity, while retaining the benefits of massive scale."**

Social supercolliders introduce unparalleled opportunities but the risks that come with such extreme access overshadow the benefits, notes Watts (2013). Indeed, many of the breakthroughs in computational social science are based on radical access to data:

> "The information we are collecting includes call logs, Bluetooth devices in proximity, cell tower IDs, application usage, and phone status (such as charging and idle), and comes primarily from the Context application." (Eagle and Pentland, 2006)[99]

Being able to access data is the first prerequisite in any analytical process. From the viewpoint of understanding and visualizing the EU economy as an ecosystem, the key context for discussing the access is the EU Balance Sheet. To utilize a permissive data access in a sustainable way, new procedures for data governance and beyond must be developed.

3.10.2. Access methods

Although there are a handful of methods for accessing data, in this document we will focus on the most used ones. We give descriptions of five categories for data access methods, that is, static datasets, Web scraping, RESTful Web APIs, query APIs, and streaming APIs.

3.10.2.1. Static Datasets

For the data provider, publishing static datasets as single document is the easiest and still often used approach. The major benefit from static datasets, also referred to as data dumps, is that the user of the dataset is able to download. However, to use such a dataset for

[99] The experiment at Stanford that was based on capturing screenshots of students' laptop screens to identify patterns in their media consumption.

analysis insists on setting up a data structure or a database before moving forward. Business intelligence tools, including Tableau and PowerBI are able to set up data sources from static CSV files and other common data dump formats.

Many of the data providers support the selection of the specific dataset for the analysis. The SDC Platinum database, for example, allows the selection of data types, time window, and a set of search options to specify the dataset to be exported.[100]

Importantly and perhaps even obviously, real-time data analysis is not possible using static datasets.

3.10.2.2. Web Scraping

In business intelligence, the data is processed for analysis through the extract-transform-load (ETL) cycle. Data science processes are often more dynamic and agile and therefore follow rather a discover-access-distill (DAD) approach (Granville, 2014). That is, new data is often discovered outside the organization, accessed with the most appropriate means, and distilled for analysis.

An important example of rudimentary data access that follows the DAD approach is web crawling and scraping. That is, data that is primarily intended for human users is collected with the help of a tailored harvesting software application that downloads web pages and extracts their data payload. Case examples on harvesting web data for research includes sourcing data on crowdsourcing campaigns (Huhtamäki et al., 2015), the global API ecosystem (Huhtamäki et al., 2017), and games as complementary products for gaming consoles (Huotari et al., 2017).

3.10.2.3. RESTful Web APIs

RESTful Web APIs functions in a client-server architecture and uses request/response paradigm where client requests for something and the server responds with the requested information. From an implementation viewpoint, the API economy is based on Web APIs that enable the machine-based access and manipulation of resources over the Web (Moilanen et al., 2019; Evans and Basole, 2016). The notion of *RESTful* refers to the Representational State Transfer (REST) software architecture (Fielding and Taylor, 2002). Put simply, the Web is a collection of services that manage resources and allow the manipulation of these resources with HTTP methods.

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[100] SDC Platinum Quick Start Guide: http://203.81.26.18:8331/Guide/SDC%20Platinum.pdf

The Twitter API is among the most popular data sources on the Web. To collect tweets that use the hashtag #OpenTrustFabric, a developer first has to create a developer account at Twitter and create a Twitter app for the collector application. The Twitter app is used to generate authentication tokens that enable connecting to the API.

Once the access is enabled, the application that is developed to access the data makes a simple HTTP GET request:[101]
https://api.twitter.com/1.1/search/tweets.json?q=%23opentrustfabric

The Twitter API provides the search results in JSON format. Listing 1 presents an example.

Listing 1: Twitter JSON


```
{
 "statuses": [
  {
   "created_at": "Tue Sep 03 11:45:52 +0000 2019",
   "id": 1168852607919697920,
   "id_str": "1168852607919697920",
   "text": "RT @TraktiCom: @jnkka Very interesting paper for our contract
        modelling research and project #opentrustfabric initiative
        @CommonAccord @gig\u2026",
   ...
   }]
}
```


3.10.2.4. Query APIs

Implemented correctly, Query APIs present an expressive way to provide access to data. Query APIs are often associated with Semantic Web technologies and in particular SPARQL, a query language designed for Resource Description Framework (RDF), the core description language in Semantic Web. However, the logic of the SPARQL as a query language that is based on triplets – instances of subject-predicate-object combinations that, with the help of unique identifiers for each category – extend beyond RDF and Semantic Web,

[101] https://developer.twitter.com/en/docs/tweets/search/api-reference/get-search-tweets.html

The example in Listing 2 indicates the expressive power of a Query API. The query selects all the music genres available in Wikidata and uses the rendering a rendering engine to visualize the interconnections between the genres as a graph.

Listing 2: SPARQL example that selects music genres available in Wikimedia

```
#graph rendering could be slow due to large number of results
#defaultView:Graph
SELECT ?item ?itemLabel ?_image ?_subclass_of ?_subclass_ofLabel
WHERE {
 ?item wdt:P31 wd:Q188451;
     wdt:P279 ?_subclass_of.
 SERVICE wikibase:label { bd:serviceParam wikibase:language "[AUTO_LANGUAGE],en". }
 OPTIONAL { ?item wdt:P18 ?_image. }
}
```

3.10.2.5. Streaming APIs

Streaming APIs invert the conversational nature of RESTful API, where a server sends update to the client when an update is ready. To develop visualizations and other applications that operate on a real time, the most straightforward architectural approach is to connect the application to a live stream of data. To continue the Twitter example, Twitter provides several alternative means to source tweets in real time, including PowerTrack, Volume (e.g. Decahose, Firehose), and Replay. The principle in all these approaches is similar. The developer of an application defines a set of keywords, registers the query to Twitter with a callback connection that is used to feed the tweets to the application.

Listing 3 presents a simplified example of registering a search term and processing the resulting data stream.

Listing 3: Processing a data stream with Python

```
from tweepy.streaming import StreamListener
from tweepy import OAuthHandler
from tweepy import Stream
import json
…
class StdOutListener(StreamListener):
   """ A listener handles tweets that are received from the stream.
   This is a basic listener that just prints received tweets to stdout.
```

```
    """
    def on_data(self, data):
        tweet = json.loads(data)
        print(tweet)


if __name__ == '__main__':
    l = StdOutListener()
    auth = OAuthHandler(consumer_key, consumer_secret)
    auth.set_access_token(access_token, access_token_secret)

    stream = Stream(auth, l)
    stream.filter(track=['#opentrustfabric'])
```

3.11. Structured Data

There is a rule of thumb in data science projects that 80% of the time is spent on collecting and cleaning the data. Both structured data and unstructured data are used to analyze business ecosystems (Basole, 2020). Even in the case of structured data, the heterogeneity of the data is a major issue in analysis (Salonen et al., 2013).

Press releases present an example of unstructured data that enables ecosystem analysis when combined with NLP. For example, Basole (2018) used NLP to extract relationships between companies and emerging technologies from public text data and used graph visualization to reveal a latent ecosystem structure.

Ecosystem analysts often rely on curated datasets (Basole et al., 2015). Curation refers to a process that seeks to ensure that data is continuously available and fit for discovery, analysis, and reuse (Lord et al., 2004). The benefits of curated data include consistent vocabulary, predictable data-gathering methods, and consistently applied data-cleaning rules. Thomson-Reuters SDC is a prominent example of curated data widely applied in academic analyses on relationships between organizations (Schilling, 2009).

Nevertheless, to enable real-time data analysis, structured data of high quality is imperative.

Creating, managing, and publishing data for machines to process at a global scale insists on a way to introduce and agree on the identities of entities and their properties represented in the data. The notion of Linked Data is "to create a network of standards-based, machine-readable data across Web sites."[102] Alternative approaches exist to represent linked data. Semantic web technologies are at the end of the spectrum. These include a range of languages from RDF to represent individual metadata instances, OWL for defining structured vocabulary referred to as ontologies, and SPARQL for querying data represented in RDF. The evolution of technologies on the Web is a function of both practitioner-driven practices that turn into *de facto* standards and co-ordinated standardization activities. Semantic Web is an example of the latter run by W3C directed by the inventor of the Web Tim-Berners Lee. On the other hand, JSON-LD stems from practitioners. JSON (pronounced "Jason") refers to Javascript Object Notation, a simple format for representing (serializing) data structures as text documents. Despite its name, JSON is widely used beyond individual programming languages in provisioning data through Web APIs. The LD extension refers to linked data. The concept of a namespace is axiomatic in enabling interoperability with minimum requirements. Let's consider a simple example of a credit card description.

Listing 4: Credit card description following example from Schema.org

```
{
 "@context": "http://schema.org",
 "@type": "CreditCard",
 "name": "Wells Fargo Secured Visa® Credit Card",
 "requiredCollateral": "Requires a minimum $300 security deposit.",
 "amount": {
    "@type": "MonetaryAmount",
    "minValue": "300",
    "maxValue": "10000",
    "currency": "USD"
 },
 "offers": {
    "@type": "Offer",
    "offeredBy": {
      "@type": "BankOrCreditUnion",
      "name":"Wells Fargo"
    },
```

102 https://json-ld.org/

```
    "priceSpecification": {
      "@type": "UnitPriceSpecification",
      "price": "25",
      "priceCurrency": "USD",
      "referenceQuantity": {
        "@type": "QuantitativeValue",
        "value": "1",
        "unitCode": "ANN"
      }
    }
  },
  "annualPercentageRate": "18.99",
  "feesAndCommissionsSpecification": "https://www.wellsfargo.com/credit-cards/secured/terms/"
}
```


3.12. Vocabulary Unification and Standardization

Data formats are not enough to unify data and ensure interoperability. Imperatively, the vocabulary that is used within the formats must be in harmony among the actors producing the data. ACTUS is an example of a standard that defines a format and vocabulary for representing financial data. ACTUS stands for Algorithmic Contract Types Unified Standards and it has two parts, data standard and algorithmic standard. The data standard “defines a universal set of legal terms – or [Contract Types] Attributes – used as parameters throughout the different financial agreements”. The Open Contracting Data Standard (OCDS) is another standard for government contracting that enables users and partners around the world to publish shareable, reusable and machine readable data, to join that data with their own information, and to create tools to analyze or share that data. Also Pan-European Public Procurement Online (PEPPOL) is another example which defines a set of artifacts and specifications enabling cross-border eProcurement in EU.

There is a tradeoff between vocabulary standardization and the flexibility and expressivity of vocabulary usage. The development of a comprehensive ontology is a significant effort. At the same time, an organically evolving and folksonomy is flexible, however prone to semantic inconsistency. Schema.org is an example of a significant collaborative activity to create and maintain vocabularies and data schemas (structures) to support semantic consistency in digital ecosystems.

In the context of modeling the the EU economy as an ecosystem through the Open Trust Fabric, vocabulary unification will be a combination of regulation, standardization, and community-based curation efforts. An approach that is, in any case, needed, is the “Authorities as Architects of the Data Ecosystem” (Gross, 2017). That is, through regulation, the authorities are in a position to define and enforce the use of formats and vocabularies for reporting to European Central Bank and other institutions. At the same time, the industry actors developing the platforms and other digital tools for Open Trust Fabric must be able to converge in defining vocabularies and formats. Schema.org is one example of such an effort and the development of JSON-LD is another. Model documents are a form of quasi-standardisation that can be quite effective.[103]

3.13. A Global Federated Alliance to Codify Contracts as an Ecosystem

Although contracting has been digitized in many organisations, the knowledge about the contracts still stays in silos as there are many different ways to draft and manage contracts; as well as that most of the existing solutions provide only the personal view about the static contract data of an organisation. Even different departments of a large organisation often use different ways to manage their contracts resulting data redundancy, poor communication, lack of standards, and higher costs when it is needed to make all contracts accessible throughout the organisation.

Another aspect of contract data is transactional data, which usually stays in a different system than the contract management system and does not capture the information about contract. As a result it becomes very difficult to reconcile static contractual data with transaction data to provide a high level view about the contract and its performance.

It becomes even more difficult when it comes to the question of providing a global view at a national or EU level as it would need to do a lot of transformation, processing and reconciliation of these contracts and transactions data. To be able to deal with these heterogeneous data, the way organizations capture, store, analyze, and distribute data must be standardized. But in reality, the contracting space is very complex and it is very difficult to define a common standard which works for all types of contracts. Also as there are already different initiatives to standardize contracts for different ecosystems (*e.g.*, ACTUS[104] for financial protocols, OCDS[105] for government contracts etc.). There is currently no way to

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[103] See for instance, the contract standards project of the IACCM (https://www.iaccm.com/contract-standards/). A very partial list of contract standards projects is at https://github.com/CommonAccord/Model_Document_Projects/blob/master/List.md

[104] https://www.actusfrf.org/

[105] Open Contracting Data Standard: https://standard.open-contracting.org

define a comprehensive standard conforming those multiple standards. An alternative solution is to initiate a "generative" process by initiating a global repository of contract templates as an Open Trust Fabric[106] (OTF).

Open Trust Fabric aims to provide a global federated ecosystem to share contract forms and components among multiple independent ecosystems in order to improve, optimise and standardise the content and use of the contracts. The main challenges of a global federated ecosystem is the absence of a common syntax and the impossibility (and undesirability) of imposing common semantics across the vast scope of contracts, with their different languages, jurisdictions, domains, objectives and factual and cultural settings. A top-down approach works for limited domains, even very important ones such as the target of ACTUS standards, but it cannot and should not encompass the vast variety of contracts generally.

We suggest an approach that parallels the success of TCP/IP. The goal of the OTF is to promote a system of transacting and relationships that is open, secure, data-minimizing and democratic. Really effective modelling requires the following:

- Common formats and labels for expressing the parameters of contracts
- A system of classification of contracts
- Shared meanings for those contracts
- Effective methods for managing and communicating the data across transaction ecosystems in a way that is secure and privacy-preserving.

Functionality and services provided by OTF will be exposed using REST API and loosely coupled with the front-end of the system. This API based approach will provide the benefit of easy integration opportunity for other third party systems.

In traditional contract management platforms, there are often two separated systems of management - the contract documents themselves and the data from and relating to the contracts. We propose a system that integrates the two aspects of the contracts: the documents and data. It's orientation is towards contract data, but the full contracts, like other important corporate documents and records are stored, preserved from tampering or inadvertent alteration, associated with other relevant transactional information, and identified for retrieval in a graph format.

[106] Open Trust Fabric: http://www.opentrustfabric.org/

As only contract data or transactions are not enough to provide an ecosystemic view of contractual relationships and other insights among different parties, we need also contractual text and metadata. OTF identifies three main phases of a contracting process which can provide both static and dynamic data to represent contractual relationships, the phases are (i) Templating, (ii) Contracting and (iii) Execution. These three phases can produce different types of data. By providing standards and tools, we can represent those data and easily reconcile them for further analysis purpose. That provides opportunities to explore the contractual relationships from different perspectives.

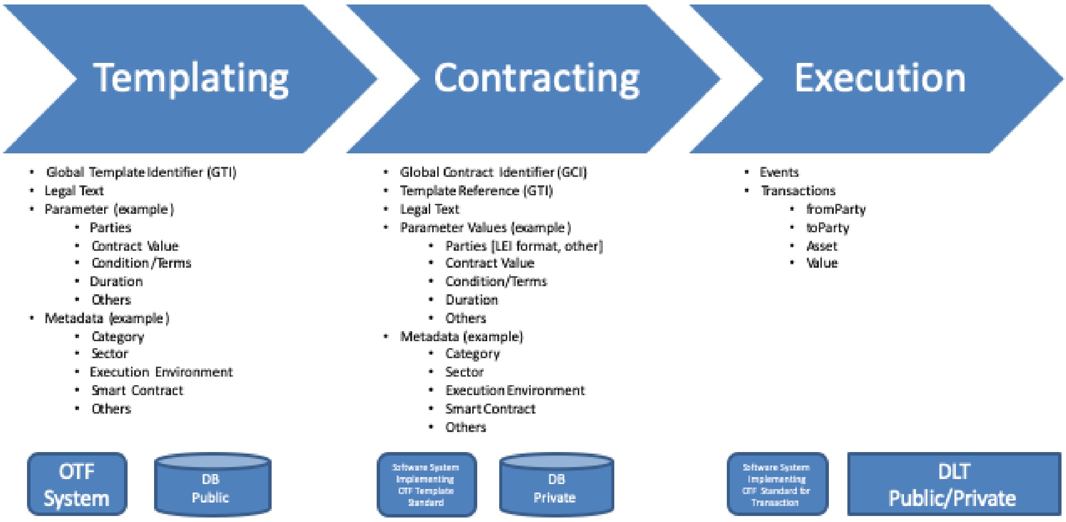

Figure 47: The OTF playfield and integration with third party's services and infrastructures.

For the Templating phase, OTF aims to provide a global federated template repository which can be governed by communities in a democratic way utilising a blockchain smart contract. It proposes an innovative approach to codify a natural language contract expressing with key and value pairs within one or many text documents.

This is some way a representation of ricardian contract which contains both legal prose and parameters which are going to be evaluated in the contracting phase. As this representation comes with a specific syntax, it could be processed by both humans and machines. Also we can transform this representation into a graph to represent the relationship among prose objects and different template documents.

The following diagram shows how a natural language contract can be codified in this new approach as text documents with key and value. Each line is represented as KEY=VALUE where value may contain text, data variable or link to other documents. These keys/values are expanded following each linked document to generate the final document.

These documents may have a special key to represent metadata information and smart contract connections.

Metadata contains information to specify static properties of the contracts which to classify and establish a relationship with other contracts. On the other hand, smart contracts contain the execution and obligation logic about the contract/clause in computable format. These codified templates work as the starting point for a contract and hosted inside a repository of contracts where different consensus mechanism can be applied to accept the changes proposed by the community who are consuming those templates. The next step is to instantiate a contract from the template, negotiate legal terms and variables between parties. End of this process leads to an agreement in natural language as well as deployment/initialisation of connected smart contract for monitoring and execution purpose.

Execution of the contract is then governed by the connected smart contract which keeps logs of every transaction with necessary metadata in blockchain. Although this text format is good enough to represent the legal prose, parameters and relationships among documents, it does not provide a way to specify more context or standardizing different concepts/vocabulary used inside the document. To overcome this limitation OTF also proposes to use json-schema format to specify the vocabulary of the contract which can be used as a standard for a specific ecosystem of contracts. Then json-ld format could be used to specify the data/metadata about the template. This approach will provide the possibility to combine legal text extended with additional data which might not be necessary from a legal perspective but will be useful for automation and analysis purposes. Also this representation with text and json format will allow to different vocabulary coming from different standards to live in a global repository.

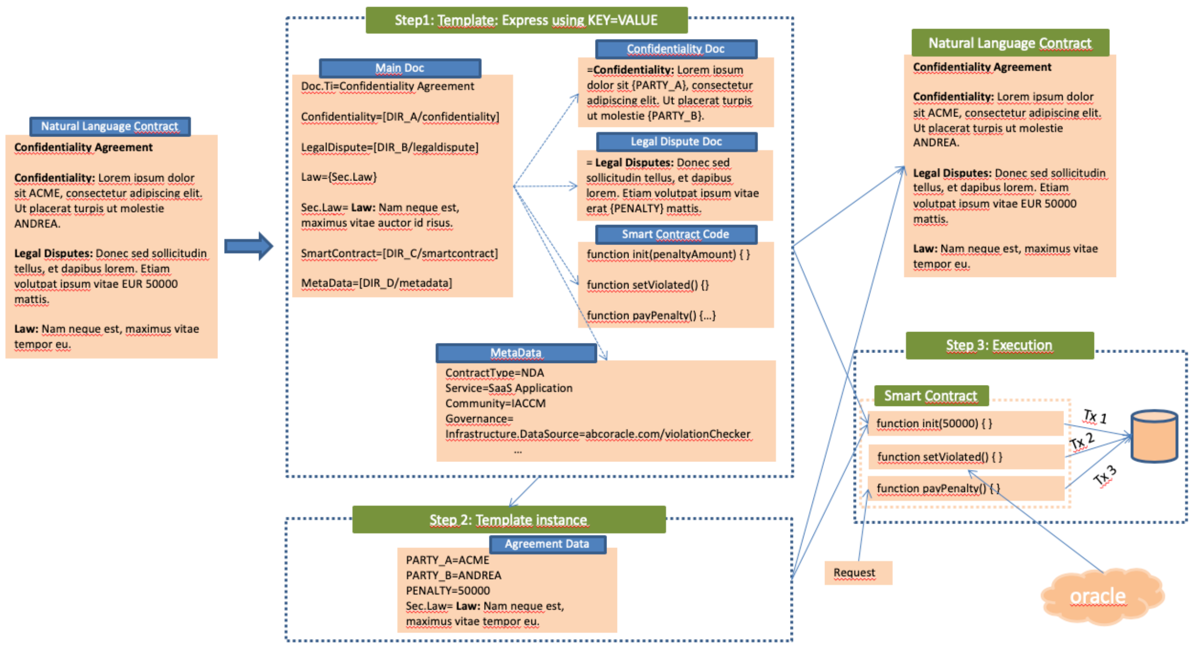

Figure 48: OTF Contract (data) representation.

In our proposed solution, we propose to divide the ecosystem of contracts into three levels namely global, community and local. The following diagram shows the concept of how a global, community and private repository of contracts could work together. There is a global public repository of contracts which are managed by a group of people/entities and can be connected with a consensus mechanism for approving changes or adding new contract documents in the repository. Anyone can pull contracts from the public repository but pushing the changes would be dependent on the governing body and the consensus mechanism of the repository.

This process would help to eventually formalize contracts as in practice similar type of contracts only a few parts are needed to be changed during the contracting phase between contracting parties.

There could be communities with their own repository and governance rules which can be connected with the public repository. These communities could be based on different interests or sectors, and can establish standard templates for contracts in the sectors of their interest. Different individuals or organisations can get contracts from the public repository, make changes according to their business needs and negotiate the contract to reach an agreement. They can also propose and push their changes into the originating repository.

Publication of a new standard or template will be governed in a democratic way by a Smart contact solution provided by OTF. We also propose to define a unique global identifier for each of the templates so that it can be easily referenced from other templates and from the contract. This will ease the reconciliation of template data with the contract data.

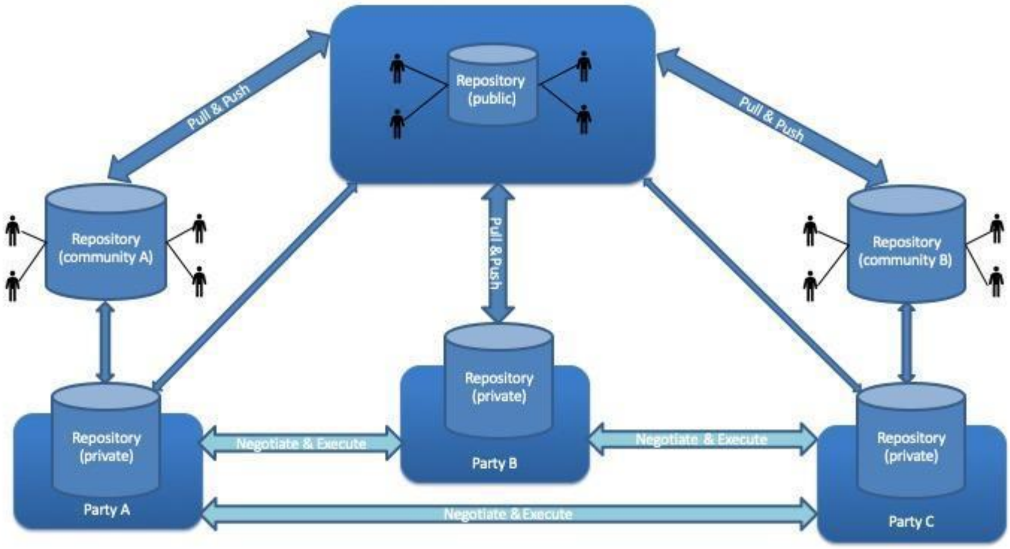

Figure 49: OTF Open Repository connection and governance.

Based on the OTF specification any existing contracting solution could be extended or any custom tools could be developed to consume and use these templates for the contracting phase. This contracting phase is more of an internal view among parties involved in a specific contract and most of the cases the contractual data should be kept private. Although the contractual data is private among the involved parties, some information might be needed by the regulation authority. They might also need the transactional data which is going to be produced in the execution phase of the contract.

As different contracting system utilises different infrastructure (e.g, centralised system, ethereum, hyperledger, corda etc.) for their implementation, there should have a common standard with the extension capability coming from the regulation authority (like electronic invoicing[107], public procurement PEPPOL[108] etc. standards) so that everyone can send the data to their DLT in a unique way. Also for each contract we propose to define a unique global identifier so that it can help to identify related data from templates, contracts and transactions.

107 https://ec.europa.eu/growth/single-market/public-procurement/digital/einvoicing_en
108 Pan European Public Procurement Online: http://peppol.eu/

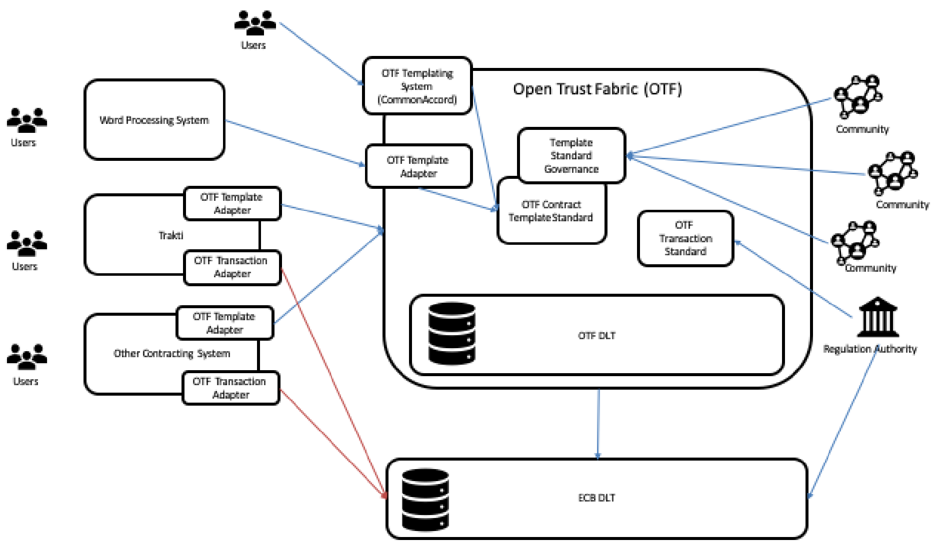

Figure 50: Open Trust Fabric high level architecture and connection with a pan european Governmental (EU/ECB) blockchain infrastructure.

Once digital data on templates, contracts, and their representative runtime output starts to accumulate, the EU regulation can enforce the organizations to perform their reporting as a digital-first, real-time process.

4. MODELLING THE EU ECONOMY AS AN ECOSYSTEM OF CONTRACTS[109]

4.1. Introduction

In this chapter, we summarise the findings of the three previous chapters and draw conclusions about what was achieved during this feasibility study.

We explain how the European Commission and other actors could successfully use the vast amount of data to better analyse the European economy and how current data sources can be combined to derive measures for the tangible and the intangible part of the economy.

We also make recommendations about how the European Commission and other actors could accelerate the transition to a fully secure, privacy-preserving transacting ecosystem; a transacting system that is simultaneously efficient, well-regulated, respectful of differences, supporting autonomy and subsidiarity, and free of proprietary lock-in.

These conclusions and recommendations are made from the perspective of better modelling and functioning of the European economy. The recommendations are also consistent with the "contract management" perspective of enterprises.

The recommendations include applying the modelling technologies to the Commission's own contract relationships linking those to the data published on the Open Data portal (Financial transparency system) and providing incentives and encouraging collaboration among private and public actors. The European Central Bank's recent report on a bank-backed digital payment system could be an important piece of an open solution.[110]

4.2. Limitations of current economic modelling

The European economy is evolving into more sophisticated and complex social structures mediated by digital communications and tools. More products and services are produced and more content and information created that can be traded remotely without physical contact. The richest economies leverage the power of networks and catalyse the contributions and assets of stakeholders into "networks."

In chapters 1 and 2, we demonstrated how digitalisation is causing economies to transition from a Fordist model of capitalism to a digital model of capitalism (Capitalism 2.1) in which different forms of capital, ownership, production means and rights are emerging.

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[109] This chapter was written by Luigi Telesca and James Hazard.
[110] ECB Innovation Lab "Exploring anonymity in central bank digital currencies" 2019 https://www.ecb.europa.eu/paym/intro/publications/pdf/ecb.mipinfocus191217.en.pdf

In a world mediated by digital communication, what is "produced" is quite different from the past; it is more centered on the intangible part of the economy. Information and attention is continuously traded by individuals and companies.

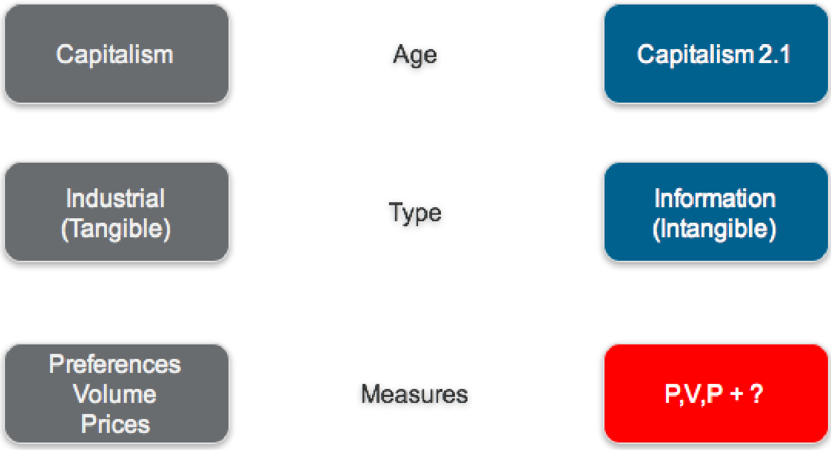

Figure 51: From Capital 1.0 to Capital 2.1.

Creative production and rights are crowd-sourced, packaged in apps and software, distributed in large scale networks with no physical retail presence, processed and used to train machines that can generate new algorithms, software artifacts and knowledge.

Although our economies are developing new value propositions and intangibles, the way that economic contributions are measured and monitored is still anchored in the past. Economic contributions cannot be limited to preferences, volumes and prices, but must also consider new economic indicators to make these values and relationships visible. As indicated by many economists (Ahmad & Koh 2011, Assa 2015, Diewert and Fox 2005, Costanza et al. 2009, Stiglitz et al. 2009, Coyle 2015, Coyle and Mitra-Kahn 2017, Brynjolfsson and Collis 2019) current economic measurement systems need to be complemented with new indicators to effectively demonstrate the value and impact of competences, skills, technology and intangibles in national accounting systems. There is a vast corpus of contributions on existing empirical studies over the years 2009-2018, well described by Roth (2019), analysing the correlation of intangible capital and labour productivity growth.

Roth and other economists demonstrate that even measuring only a small part of the intangibles gives a totally different perspective on the economy. As an example, the GDP slowdown of Western economies can be explained by the current transformation from physical to digital economies. These analyses explain how economies are transitioning, but they do not provide a complete picture.

New tools need to be created to help policy-makers go beyond the current limitations of GDP. Those tools should use real-time data and effectively map and model dynamic relations in digitised economies. They should present, in a clear analytical framework, the opportunities and challenges that digitalisation offers to the European economy. GDP measurement has been updated to account for part of intangibles, notably to include R&D investments, but this approach is very conservative since most intangibles that are part of the R&D measured are not even accounted for in balance sheets (Schreyer and Zinni 2018).

In the previous chapters 1 and 2, we demonstrated that to correctly analyse economic transactions in the modern economy, it is necessary to understand, include and monitor platform ecosystems and to map the data, transactions and relationships in the digitalised agreements between parties.

A digitalised economy offers the possibility of new and more efficient ways to encapsulate value, track relationships and measure contributions, since each event creates a digital record (digital traces) somewhere in a database that represents each increment of contractual relations agreed by the parties. The digital records are connected to parameters and access control mechanisms defined in the code of the software that address the functions of an agreed contract. The opportunity is to effectively account and reconcile the relations, assets, transactions and events with the expectations and commitments that arise from these contracts.

As the double-entry accounting system invented by Fra Luca Bartolomeo de Pacioli (Pacioli, 1494) had to evolve to cope with the complexity of cross-border trading by Venetian merchants during the Italian Renaissance, the same should happen now to correctly measure the transformative effects of our digitalised economy based on the availability of data and contracts.

Today we already have all the data needed to measure the economy as an ecosystem of contract but there is a need to go beyond that; we need to create unified, open and trusted ledgers of accounts that express the value of the digitalised economy and can account in a specific and incontestable way for the intangible assets, digital property rights and contributions that citizens and companies create in cyberspace. This new way of accounting for the invisible part of the economy will facilitate a more objective and data-driven approach to measuring economies. It will also help policy makers in testing and designing more objective measures.

4.3. The impact of the Internet and the World Wide Web on economic measures

The Internet enabled greater efficiency in many kinds of collaborations and businesses. As business discovered nearly friction-less communication, there was a wave of transformation, from General Electric's "destroyyourbusiness.com"[111] to Andreesen-Horowitz's "Software is eating the world."[112]

There was early enthusiasm that the Internet was naturally open and democratic, that removing the cost of communicating would permit people to discover the truth and to self-organise, that the value would go to the participants.[113] That democratic optimism was followed by a period of extreme consolidation based on the benefits of large aggregations of data (chapter 2).

Before the digital age, economic measurement was highly dependent on humans counting and reporting things. This required that the things being measured were important enough for someone to expend the effort to do the recording and reporting, and that the items measured were sufficiently objective and observable to make the measurements meaningful. To meet this need, many companies had to internalise production factors and increase labour costs to facilitate data entry, data curation and product and service monetisation.

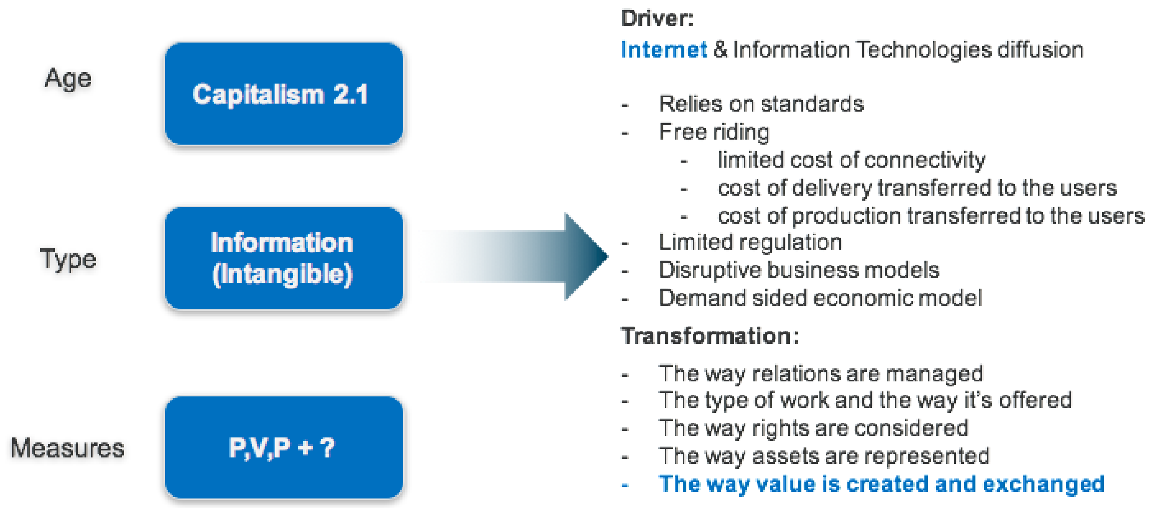

Figure 52: Capital 2.1 - main driver and effects.

Information and communication technologies (ICT) and the Internet (broadly defined) have transformed the depth and breadth of data that can be recorded and analysed. With the penetration and adoption of smartphones, IoT and Alexa-like tools, there has been an explosion in the volume and range of user-generated data. Sensors now measure a vast variety of data points, including things that escape human detection. Many people routinely travel

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[111] https://www.economist.com/special/1999/09/16/dybcom.
[112] https://a16z.com/2011/08/20/why-software-is-eating-the-world/
[113] https://www.eff.org/cyberspace-independence

with tracking devices, that report every movement, every heartbeat, every interaction.[114] Shipping containers are being outfitted with devices that measure and report location, temperature, chemistry and vibration. Tracking is being applied to individual items of inventory, from aircraft parts to vegetables. Data from sensors now can be communicated and stored securely and efficiently.[115]

4.4. Methodologies to Achieve a Satisfactory Modelling Result

To have a good picture of an economy it is not enough to have access to data. It is necessary to understand the economy's contracts. In this context we use "contracts" to mean the documentary artifacts that formalise transactions, relationships and events under them (Suchman 2003). These contracts can be expressed as formal documents, often in Word or PDF, as web-based terms of use in HTML, and as smaller datagrams such as invoices, payments, receipts and notices under contracts in electronic systems.

Contracts provide the structure for relationships in ways that can be orthogonal to events conventionally measured for economic purposes. They express structures of ownership, control, connection, obligation, conditions and consequences. These structures include intellectual property, licenses, liens and pledges, ownership holdings, guarantees and insurance. They can be nearly invisible from a measurement point of view until circumstances change, when they may suddenly become absolutely important. Deep structures, insights, preferences and risks are expressed in contracts. Contracts also express expectations and compromises, attempts to reconcile competing interests among parties and other affected persons: the social context.

In chapter 3 we explained in detail how our Prose Object model permits all "things" relevant to our economic study to be expressed as objects in a contract graph, facilitating data analysis and offering a deeper view of our economies.

The primitives or graph "entities" in a contract graph include:

1. *Communities, Parties, Actors*.
2. *Services, Assets* (tangible and intangible).
3. *Governance, Events* (places, geographic coordinates, jurisdictions, postal addresses, events under contracts, sections of contracts, payments, deliveries, returns, confirmations and the like).

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[114] Mobile telephones data collection for Parkinson's disease. https://parkinsonsnewstoday.com/2016/03/07/sage-bionetworks-releases-first-of-its-kind-data-from-parkinsons-iphone-study/

[115] Regarding secure methods for handling data, see for instance Trust::Data at MIT. https://trust.mit.edu .

4. *Infrastructure*, *Data* (physical, digital, Smart Contract code, data sources).
5. *Patterns* (prototypes for contracts).

These can all be expressed as "records" formatted as lists of "key/values" (pairing a label with a string of text) and some references to other records (collectively forming a "graph"). These keys/values are expanded following each linked record to generate full documents. These documents each have a unique ID to identify the type of contract and special key to represent metadata information (context) and Smart Contract connections as depicted in Figure 40.

Parameters include “deal points” such as dates, amounts, and special requirements that inform both the Code (automatic execution) and the Prose (legal meaning and intention of the parties). The line between Parameters and Prose is not absolute, and a real system must allow variation of both. The Code can be executed in centralised or distributed infrastructures, like Distributed Ledger Technologies (DLT) and Blockchains, to implement the agreement of the parties and to adapt autonomously to programmed events and generate transactions.

Metadata can contain information to specify static properties of the contracts that classify and establish relationships with other contracts (IDs). Smart Contracts complement Prose Objects, providing the execution and obligation logic about the contract/clause in computable format connected to a specific infrastructure (e.g. Ethereum) and Smart Contract language (e.g. Solidity).

As explained above, to enable analysis each codified contract has a unique global identifier so that it can be easily referenced from other templates, standards, transactions and events and from a master contract. This will ease the reconciliation of template data with the contract data.

In chapter 3, we explained how data can be matched, connected and analysed using contract graphs, algorithms and pattern recognition (AI) to draw conclusions rapidly and deeply, even in distributed systems.

4.5. Availability and accessibility of new data types and sources

The opportunity presented by the flood of new data is enormous. The potential impact of capitalisation of intangibles and effective data management for an economy is suggested by the impact that it is already having on particular businesses. A business that has good control of data can radically improve its operations, identify trends, react quickly and discover correlations that were previously unmeasured or unidentified (an example is Nowcasting with Google Trends).

We demonstrated in chapter 3 that there are already many methods and accessible data sources that could be consumed and analysed. Most of the data needed to monitor the EU economy can be accessed via APIs or Open Data Portals. Everyday we produce an amount of data that globally reaches more than 40 Zettabytes a year and growing.

Certain qualified data sources will need to be compensated, but public information can complement private data sources. GDPR, e-invoicing and PSD2 are giving new qualified data sources that can be used for analysis. There are more than 22.000 APIs available in the world (ProgrammableWeb)[116] and only in EU we can access at national and European level around 14.064 Datasets to measure the state of the economy (European Data Portal). Furtheremore, Basole (2020), see Table 3, identifies and categorizes 170 high quality data sources that are fully accessible and can be used for the second part of the study.

Thanks to Basole's work and our socio-technical approach to classifying contracts, ecosystem data offers a new opportunity to monitor and measure economic ecosystems and correctly report unpaid services (Coyle 2015) and accounts for intangible assets as proposed by Sveiby (1998).

Sveiby's work inspired us to model a business ecosystem of contributions by measuring:

1. **Individual Competence -** coming from personnel and embedded in the way they share and enrich knowledge among each other;
2. **Internal Structure -** represented by the structure and the protocols and data, they generate and share using the technology;
3. **External Structure -** represented by the ecosystem they put in place to nurture and magnify those links.

This led us to consider how those data sources can be combined and used for the different dimensions and entities at stake to describe the economy as a dynamic ecosystem. We also integrated new data sources (e-Identity, e-Invoicing, PSD2 and GDPR data) to cover the household and the government dimensions.

[116] https://www.programmableweb.com/apis/directory

Table 6: EU Economy Modelling Data Framework

Type/Group	Households	Corporations	Governments	Data Sources
Individual Competence	**Actors (H)** Family Member	**Actors (H)** Executive - Leadership Board Members Inventors	**Actors (H)** Political Leadership Cabinet Members Executives	Public filings Digital Identity Systems
	Network/Relation Social and Professional	**Network/Relation** Social and Professional	**Network/Relation** Social and Professional	Public filings Social Media Press Releases Events repositories
	Assets Data Capital Health Education Social Reputation* Privacy* Leisure*	**Assets Data** Capital Health Education Social Reputation* Privacy* Leisure*	**Assets Data** Capital Health Education Social Reputation* Privacy* Leisure*	Public filings Banking data Property and Land Registries Health data Social media Gig economy data Patent information Open Source repositories Mobile phone data App Store data
Internal Structure	**Actors (H)** Parents Partner(s) Children	**Actors (H+T)** Business Units Investors* Partners Developers* Prosumers*	**Actors (H+T)** Business Units Governments Citizens*	Public and corporate filings Social Media Corporate Website Investments, Acquisitions, Merges, Litigations Open Source repositories e-Invoicing* Privacy policy*
		Infrastructure - HW+SW* Protocols - SW* Boundary Resources*	Infrastructure - HW+SW* Protocols - SW* Boundary Resources*	Corporate User generated data* Infrastructures and sensor data App Store data Presentations Product and Services data* Open Source repositories
	Network/Relation Social and Professional	**Network/Relation** Social, Professional & Technical	**Network/Relation** Social, Professional & Technical	Public filings Corporate Website Privacy policy* Investments, Acquisitions, Merges, Litigations Consortia and membership list Social Media Annual reports Press Releases Events repositories Open Innovation Portals

	AssetsData Capital Health Education Social Reputation* Privacy* Leisure*	**AssetsData** Capital Education Social Reputation* Privacy*	**AssetsData** Capital Health Education Social Reputation* Privacy*	Developer Forums Public and corporate filings Banking data Property and Land Patent information Social media e-Invoicing* Product and service data* User generated data* Open Source repositories* App Store data Registries
External Structure	**Not Applicable**	**Actors** Consumers Suppliers Regulatory bodies Infrastructure - HW+SW* Protocols - SW* **Network/Relation** Social, Professional & Technical **Assets Data** Capital Social Reputation* Privacy*	**Actors** Citizens Regulatory bodies Suppliers Infrastructure - HW+SW* Protocols - SW* **Network/Relation** Social, Professional & Technical **Assets Data** Capital Social Reputation* Privacy*	Public and corporate filings e-Invoicing* Privacy policy* Corporate Presentations Product and Services usage data* User generated data* Infrastructures and sensor usage data* App Store data Annual reports Privacy policy* Social Media Events repositories Knowledge Based Repositories Public and corporate filings Banking data Social media e-Invoicing* Product and service data* App Store data Registries

Basole (2020) also offers us a non-conclusive list of 107 data sources that could be used and combined to analyse ecosystems, including the availability of ecosystem primitives (Organizational (Org); Human (Hum); Technology and Artifacts (T+A); Relationship and Activities (Rel+Act)).

Table 7: Core Ecosystem Data Sources/Providers (Basole, 2020)[117]

#	Source	Org	Hum	T+A	Rel+Act
1	Aberdeen	X	X		X
2	AlternativeTo	X		X	X
3	AngelList	X	X		
4	App Annie	X		X	X
5	Apptopia	X		X	X
6	Barchart			X	X
7	Bazaarvoice		X		X
8	Bitbucket		X	X	X
9	Bloomberg	X	X	X	X
10	Bloomberg Tradebook				X
11	BoardEx	X	X		X
12	Bombora	X	X		X
13	Builtwith			X	X
14	Bureau van Dijk	X	X		X
15	CareerBuilder	X	X		X
16	CB Insights	X	X	X	X
17	Cigital			X	X
18	Comscore	X	X		X
19	CoRepo	X	X		X
20	Corporate360	X	X		X
21	Crunchbase	X	X	X	X
22	Data.com	X	X	X	X
23	Datafox	X	X	X	X
24	Dealflow	X	X		X
25	Demandbase	X	X		X
26	Digimind	X		X	X
27	DiscoverOrg	X			X
28	Dow Jones	X	X	X	X
29	Duedil	X	X	X	X
30	Dun & Bradstreet	X	X		X
31	Dun & Bradstreet Credibility Corp	X			X
32	Enigma	X	X		X
33	Euromonitor International			X	X
34	F6S	X		X	X
35	Facebook	X	X		X
36	FactSet	X	X		X
37	FullContact	X	X		X
38	G2 Crowd	X	X		X
39	GitHub	X	X	X	X
40	GitLab		X	X	X
41	Glassdoor	X	X		X
42	Google	X	X	X	X
43	GrowthIntel	X	X		X
44	Hoovers	X	X		X
45	IBISworld	X	X		X
46	Indeed	X	X		X
47	Infogroup	X	X		X
48	Innography	X	X	X	X
49	InsideView	X	X		X
50	IPlytics	X		X	X
51	Knoema	X	X		X
52	LeadIQ	X	X		X
53	LeadsAI	X	X		X
54	Leadspace	X	X		X
55	LexisNexis	X	X		X
56	LinkedIn	X	X		X
57	Macrobond	X	X		X
58	Mattermark	X			X
59	Mergermarket	X	X		X
60	Mintel	X	X		X
61	Morningstar	X	X		X
62	MSCI	X			X
63	Nasdaq	X			X
64	Northern Light	X	X	X	X
65	NPD	X		X	X
66	Owler	X	X		X
67	PatSnap	X			X
68	Payscale	X	X		X
69	PitchBook	X	X		X
70	Plainsight Intel	X			X
71	Preqin	X			X
72	PrivCo	X	X		X
73	Product Hunt	X		X	X
74	ProgrammableWeb	X		X	X
75	Quandl	X			X
76	Radius	X			X
77	RainKing	X	X		X
78	RelPro	X	X		X
79	RelSci	X	X		X
80	Reuters	X	X	X	X
81	S&P Global Market Intelligence	X	X	X	X
82	Salesloft	X	X		X
83	SeedInvest	X			X
84	SelectHub	X		X	X
85	SEMrush			X	X
86	Siftery	X		X	X
87	SimilarWeb	X		X	X
88	Slideshare	X	X	X	X
89	Spiderbook	X	X	X	X
90	StackOverflow		X	X	X
91	Startup Ranking	X			X
92	Techcrunch	X	X	X	X
93	Thomson Reuters	X	X	X	X
94	Tracxn	X	X		X
95	Trustpilot	X			X
96	TrustRadius				X
97	Twitter	X	X	X	X
98	USPTO			X	X
99	VC Experts	X	X		X
100	Vertical Knowledge	X			X
101	Wefunder		X		X
102	Wikipedia	X	X	X	X
103	Xignite	X	X		X
104	Xing	X	X		X
105	ZipRecruiter	X	X		X
106	Zirra	X	X	X	X
107	ZoomInfo	X	X	X	X

As listed in Table 7, in order to analyse the entire EU ecosystem or a market vertical we need to aggregate additional data from formal and informal sources that offer insights about the transactions, intangibles and the overall (contractual) relationships. Those data sources are considered additional to the data already collected for GDP and are considered to complement GDP measures with satellite indicators (Brynjolfsson & Collis, 2019).

4.6. Conclusions

As already stated in chapter 3, our research review shows that data already exists or is becoming available to conduct ambitious research on the ecosystem nature of the economy and the risks embedded in the current financial system.

The data on contractual relationships between actors, both business-to-business and consumer-to-business, provides a potential starting point for understanding and visualizing the EU economy as an ecosystem. GDPR, e-invoicing and PSD2 data combined with the listed data sources described in the previous sections gives us all the tools to run a complete modelling exercise.

Implementing the Open Trust Fabric (OTF) methodology and architecture, fully described in chapter 3, would permit regulators and enterprises to have “real time” analytics of their ecosystems, including eventually the entire EU economic ecosystem. Financial

[117] Countesly https://scholarspace.manoa.hawaii.edu/handle/10125/64444

Identification (LEI[118]) and Contract Identification from the OTF will offer a unified view of the economic ecosystem and all transactional records required for regulatory purposes that can be stored in a unified distributed infrastructure catalysed by ECB and the EU Commission, with nodes hosted by all EU Member States.

Furthermore, the Triple Entry Accounting approach (Grigg 2015) connected to classified contracts via OTF and standardised IDs, could facilitate the verifiable measurement and accounting of tangible and intangible assets. This would leverage one of the most fundamental uses of blockchain technology, in which all accounting entries of outside parties involved in the transaction are cryptographically sealed and linked through a Smart Contract to a third entry. In this approach, transactions go through a contract in real time maintained by a third-party agent or entry (blockchains like Ethereum, Corda or others) which both parties connect to and agree on. This Smart Contract includes everything about the transaction (supplier, buyer, goods, services, prices, relationship). So the bookkeeping entries of all parties are aligned and provable.

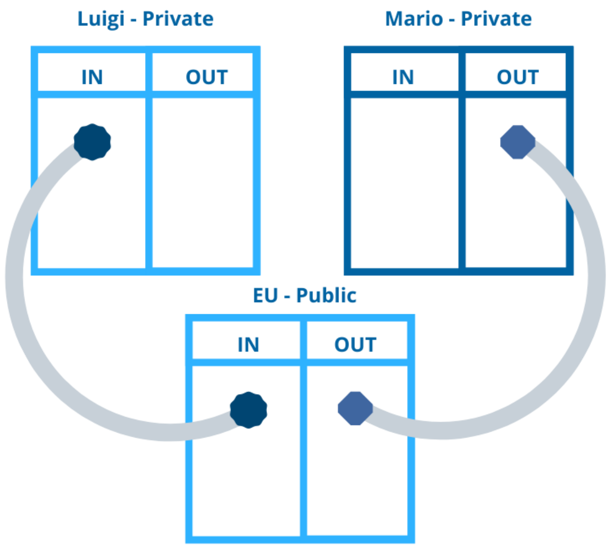

Figure 53: Triple accounting system.

The OTF initiative can be instrumental to current efforts in Europe to make the economy more efficient and secure and the current investments agreed by the Member States with the European Commission for the development of a European Blockchain Services Infrastructure (EBSI) that will support the delivery of cross-border digital public services.

The OTF libraries can be coordinated and accelerated by collective action - that’s why it is called an “Open Trust Fabric.” Legal terms are essential social structuring elements.

[118] https://www.gleif.org/

There is a need for public interest governance of the Prose Object legal materials, a legal equivalent of the Linux Foundation. This might be a new organisation, a function of an existing organisation, or a collaboration among organisations.

A prudent transacting system should seek to empower actors, not to supplant them with unknown entities, to retain social infrastructure and institutional knowledge, not to supplant it with untested theories. A prudent system will empower immediately productive actors, trustworthy data fiduciaries, and "decision fiduciaries" such as agencies and courts. In this perspective, there are already many appropriate actors whose efforts could be coordinated. These actors include contract negotiators, lawyers, government agencies, banks and coders in law, business and academia. An important goal is to bring such actors into the discussion about a common model of transacting. This can be done most effectively by using the format that is already widely used in law, documents, in the great range of human languages that people use. A proper goal is to make existing institutions more efficient rather than supplant them.

In the long run, to offer a stable and satisfactory result and fully implement the OTF approach and infrastructure proposed in chapter 3, these actors must evolve towards:

A. **Common or convertible data labels:** Transaction reporting needs to use labels (tags or keys) that are consistent or can be mapped to one another. It makes no difference if the price or delivery date of something is expressed as "price," or "prix" or "Preis", if the terms refer to the same kind of thing.
B. **Consistent transaction classifications and semantics:** To aggregate information about "price/prix/Preis," or any other Parameter, similar transactions must be classified together. The above depend on consistent "transaction semantics" - the meanings of the Parameters in the context of the underlying contracts. Transaction semantics can be approximated *post-hoc* via NLP analytics, but it is a rough approximation, susceptible to errors and misses the legally important element of "intention of the parties" that authoring provides. Consistent semantics can be iteratively achieved by referencing standards.
C. **Common data exchange mechanisms:** PSD2 and GDPR require API-based data exchanges. These present enormous security challenges, but new technologies enable radical improvements in the management of data and the reduction of attack surfaces. A transition to this model seems compelled by the security risks of concentrations of confidential and personal data.

D. Incentives for enterprises and others to adopt such systems: No single entity can hope to dictate standards for all of transacting everywhere. Any such centralised effort would have to be grossly reductive and would run the dangers of any centralised approach. Instead, by offering immediate benefits of collaboration for early adopters such as enterprises, the existing contract ecosystem of parties, lawyers and agencies can be drawn into standards creation. This avoids the top-down problem of standards, while creating a truly decentralized and secure platform. It directly imitates the open source dynamic of software development.

4.7. Recommendations

Based on analysis and activities performed in the feasibility study, we recommend the European Commission to accelerate the transition to a structured approach to contracts and Open Trust Fabric implementation with actions such as the following:

- Encourage the standardisation of contract semantics by:
  - Publishing some of the EU's own contract forms in Prose Object format, with an appropriate API, in multiple languages.[119]
  - Encourage submissions and negotiations in Prose Object format.
  - Encourage European initiatives on machine learning-based structuring of contract forms and related materials as references and raw materials.
  - Encourage expression of financial information using an extensible system of tagging and classification that ties into contract semantics.[120]
  - Coordinate with groups such as IACCM, the Paris Call for Trust and Security in Cyberspace, France's Cercle Montesquieu and organisations in law, such as UNIDROIT, the European Law Institute, and UNCITRAL.
  - Coordinate with legal innovation programs such as AssasLegalInnovation.com and LegalHackers.org.

- Encourage standardisation of technical platforms by:
  - Coordinate with API-economy initiatives such as those in the financial sector for PSD2 compliance and in the broader economy for GDPR compliance stimulating the publication of Terms of Service and Privacy Policy in fully computable and readable format following the suggested OTF graph approach.

[119] For instance, EU General Conditions for Contracts
http://www.commonaccord.org/index.php?action=list&file=G/EU_Europa_EC_Conditions_General/

[120] Taxonomies such as LEI and ACTUS can be powerful drivers of standards and adoption of graph tools. See, e.g. http://www.commonaccord.org/index.php?action=list&file=G/ISO-ELF/Type/
http://www.commonaccord.org/index.php?action=doc&file=G/GalionProject-TermSheet-CmA/Demo/Acme-SeriesA.md#Company.ELF.Code)
http://www.commonaccord.org/index.php?action=list&file=G/ACTUS/Taxonomy/

    - Coordinate with Blockchain and Smart Contract efforts - such as the Linux Foundation, the W3C's Interledger and semantic web initiatives, the Accord Project, Ethereum Foundation, France's LaBChain, and many others. Even the current mega-platforms are now in a process of convergence because their business models overlap and because of public pressure regarding data governance, curation and monopoly power.[121]

- Encourage the development of an ecosystem of open transacting by:
    - Initiatives regarding standardizing legal text for:
        - data governance and data security.
        - health data, frameworks, consents and the like (health data is strongly bound to legal requirements and government programs)
        - start-up companies (startups have high legal needs, strong technical skills and low barriers to decision).
    - Initiatives with local and national governments.
    - Initiatives in insurance. Insurance aggregates risk and depends on an ecosystem view that parallels that of regulators but can be more dynamic because it is market-based and transaction level.

- Review financial reporting requirements.
    - Structured information and API-based transacting enable reporting that is both much more accurate and precise, and much more current. With APIs, that information can traverse supply chains much more effectively.

A critical concept underlying these recommendations is the "generative" element.[122] Instead of seeking to define a complete complex system, we recommend keeping the initial focus on the syntax, starting from the Prose Object format. The success of the Internet as an ecosystem can be understood as being the result of minimum viable standardization by defining a single "layer" of standardization, with all other layers being free for innovation. The key/values and links of Prose Objects are a minimum viable standard for the organisation of transaction data into structured graphs.

[121] See Smith and Brown (2019) and Dorsey, Twitter thread on Decentralized Standard for Social Media https://twitter.com/jack/status/1204766087281172480 2019.
[122] "The Generative Internet" Zittrain, 2006 https://papers.ssrn.com/sol3/papers.cfm?abstract_id=847124

5. REFERENCES

Ahmad, N. & Koh, S.-H. (2011). Incorporating Estimates of Household Production of Non-Market Services into International Comparisons of Material Well-Being. OECD Statistics Working Papers, Paris: OECD.

Ahmad, N., & Ribarsky, J. (2018). Towards a Framework for Measuring the Digital Economy, http://www.oecd.org/iaos2018/programme/IAOS-OECD2018_Ahmad-Ribarsky.pdf

Allee, V. (2003). *The future of knowledge: Increasing prosperity through value networks*. Butterworth Heinemann, Elsevier Science.

Andersson, M. & Saiz L. (2018). *Investment in intangible assets in the euro area*. Published as part of the ECB Economic Bulletin, Issue 7/2018.

Andriessen, D. (2004). Making Sense of Intellectual Capital: Designing a Method for the Valuation of Intangibles. Elsevier.

Annual mobile app revenues worldwide by store 2023 | Statista. (2018). https://www.statista.com/statistics/747489/annual-consumer-spend-mobile-app-by-store/

Arvin, M. and Pradhan, R. (2014) “Broadband penetration and economic growth nexus: evidence from cross-country panel data”. Journal of Applied Economics, Volume 46 - Issue 35

Assa, J. (2015) ‘The financialization of GDP: Essays in the political economy of national accounting’, Thesis dissertation, The New School: ProQuest Dissertations Publishing.

Basole, R. C. (2020). Understanding Ecosystem Data. In HICSS 2020 Proceedings (p. 10).

Basole, R. C., Russell, M. G., Huhtamäki, J., Rubens, N., Still, K., & Park, H. (2015). Understanding Mobile Ecosystem Dynamics: A Data-Driven Approach. ACM Transactions on Management Information Systems, 6(2), 32. https://doi.org/10.1145/2724730

Basole, R. C., Srinivasan, A., Park, H., & Patel, S. (2018). ecoxight: Discovery, Exploration, and Analysis of Business Ecosystems Using Interactive Visualization. ACM Transactions on Management Information Systems, 9(2), 1–26. https://doi.org/10.1145/3185047

Bellinger G., Castro D., Mills A., Data, Information, Knowledge and Wisdom, http://www.Systems-thinking. org/dikw/dikw.htm, 2004. Google Scholar

Bendoly, E., & Clark, S. (Eds.). (2017). Visual Analytics for Management: Translational Science and Applications in Practice. New York, New York, USA: Taylor & Francis / Routledge.

Betza, F., Oprică, S., Peltonen, T. A., & Sarlin, P. (2014). Predicting distress in European banks. Journal of Banking & Finance, 45, 225–241. https://doi.org/10.1016/J.JBANKFIN.2013.11.041

Bijker, W. & Pinch, T. (1987). The Social Construction of Facts and Artifacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other.

Bonabeau, E. (2002). Agent-based modeling: methods and techniques for simulating human systems. Proceedings of the National Academy of Sciences of the United States of America, 99(suppl 3), 7280–7287. https://doi.org/10.1073/pnas.082080899

Botto, F. & Passani, A. (2007). The Relationship Between Community Networks and Digital Ecosystems. European Commission FP7 “OPAALS” project Deliverable 7.1.

Brynjolfsson, E. and Collis A. (2019), How Should We Measure the Digital Economy?, Harvard Business Review:

Brynjolfsson, E., Collis, A., Diewert, W. E., Eggers, F. and Fox, K.J., (2019) GDP-B: Accounting for the Value of New and Free Goods in the Digital Economy. NBER working papers

Castro, G. M., Delgado-Verde, M., Amores-Salvadó, J., & Navas-López, J. E. (2013). Linking human, technological, and relational assets to technological innovation: exploring a new approach. Knowledge Management Research & Practice, 11(2), 123–132. https://doi.org/10.1057/kmrp.2013.8

Chapman, P., Clinton, J., Kerber, R., Khabaza, T., Reinartz, T., Shearer, C., & Wirth, R. (2000). CRISP-DM 1.0: Step-by-step data mining guide.

Choudary, S.P., Alstyne, M.W., & Parker, G. (2016). Platform Revolution: How Networked Markets Are Transforming the Economy--and How to Make Them Work for You.

Cioffi-Revilla, C. (2010). Computational social science. Wiley Interdisciplinary Reviews: Computational Statistics, 2(3), 259–271. https://doi.org/10.1002/wics.95

Conway, N. and Sturges, J. (2014) ‘Investigating Unpaid Overtime Working among the Part-time Workforce’, British Journal of Management 25, 755–771.

Costanza, R., d'Arge, R., de Groot, R., Faber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P., van der Belt, M., (1997) 'The value of the world's ecosystems and natural capital', Nature 387, 253–260.

Costanza, R., Hart, M., Posner, S. and Talberth, J. (2009) 'Beyond GDP: The Need for New Measures of Progress', The Pardee Papers No. 4, Boston University.

Coyle, D. (2015) 'Commentary: Modernising Economic Statistics: Why It Matters', National institute economic Review No. 234.

Coyle, D. (2017) 'Do-it-yourself digital: the production boundary and the productivity puzzle', ESCoE Discussion Paper 2017-01.

Coyle, D. and Mitra-Kahn, B. (2017) 'Making the future count', entry to the Indigo Prize, available at:

Damodaran, A. (2014, June). Uber Isn't Worth $17 Billion. FiveThirtyEight.

Darmstadter, H. (2010). Precision's Counterfeit: The Failures of Complex Documents, and Some Suggested Remedies. The Business Lawyer, 66(1), 61-83.

Davis, J. P., Eisenhardt, K. M., & Bingham, C. B. (2007). Developing Theory Through Simulation Methods. Academy of Management Review, 32(2), 480–499. https://doi.org/10.5465/AMR.2007.24351453

Demunter, C (2018), "Towards a Taxonomy of Platforms in the Collaborative Economy: Outcomes of a Workshop on Measuring the Collaborative Economy", presented at the 2018 OECD Workshop on Online Platforms, Cloud Computing and Related Products, 6 September.

Diewert, W. and Fox, K. (2005) 'The New Economy and an Old Problem: Net versus Gross Output', Working Paper (2005/02), Centre For Applied Economic Research.

Diewert, W.E. and N. Huang (2011), "Capitalizing R&D expenditures", Macroeconomic Dynamics, Vol. 15, pp. 537-564.

Eagle, N., & (Sandy) Pentland, A. (2006). Reality Mining: Sensing Complex Social Systems. Personal Ubiquitous Computing, 10(4), 255–268. https://doi.org/10.1007/s00779-005-0046-3

Ehrlich, E. (2013). Executive Summary: New Directions for Youth Development. Progressive Policy Institute, 2013(139), 5–8. https://doi.org/10.1002/yd.20064

Eisenhardt, K. M., & Santos, F. M. (2001). Knowledge-Based View: A New Theory of Strategy? In Handbook of Strategy and Management (pp. 139–164). London, United Kingdom: SAGE. https://doi.org/10.4135/9781848608313.n7

European Commission et al. (2009), System of National Accounts 2008, United Nations, New York, http://unstats.un.org/unsd/nationalaccount/sna2008.asp.

Evans P.C. and Basole R.C. (2016), Revealing the API ecosystem and enterprise strategy via visual analytics, Commun. ACM 59, 2 (January 2016), 26-28. DOI: https://doi.org/10.1145/2856447

Fielding, R., & Taylor, R. N. (2002). Principled Design of the Modern Web Architecture. ACM Trans. Internet Technol., 2(2), 115–150. https://doi.org/10.1145/514183.514185

Fioramonti, L. (2013) Gross domestic problem: The politics behind the world's most powerful number, Zed Books.

Granville, V. (2014). Data Scientist versus Data Engineer. https://www.datasciencecentral.com/profiles/blogs/data-scientist-versus-data-engineer

Grigg I. (2000), "Financial Cryptography in 7 Layers," 4th Conference on Financial Cryptography, Anguilla, Springer-Verlag LNCS 1962. All papers are at http://iang.org/papers/

Grigg, I. (2005). Triple Entry Accounting. 10.13140/RG.2.2.12032.43524. Available at https://www.researchgate.net/publication/308640258_Triple_Entry_Accounting

Grigg I. and Howland G (1997) as part of the Ricardo payment system.

Gross, F. (2017). Artificial Senses: Measuring finance and the economy at the speed and scale relevant in the digital age. European Central Bank.

Gurley, B. (2014). How to Miss By a Mile: An Alternative Look at Uber's Potential Market Size. Above the Crowd.

Hardjono T., Pentland A., Shrier D. (2016), eds., in Trust::Data—A New Framework for Identity and Data Sharing. Visionary Future.

Hardy, (1980). "The role of the telephone in Economic Development", Telecommunications Policy, 4 (4), pp.278-286.

Harrison, J. R., Lin, Z., Carroll, G. R., & Carley, K. M. (2007). Simulation Modeling in Organizational and Management Research. The Academy of Management Review, 32(4), 1229–1245.

Hart O. & Holmström B. (1986), The Theory of Contracts, Working paper, dept. of economics, Massachusetts Institute of Technology.

Hazard J. & Haapio H. (2017), Wise Contracts: Smart Contracts that Work for People and Machines, Erich Schweighofer et al. (Eds.), Trends and Communities of Legal Informatics. Proceedings of the 20th International Legal Informatics Symposium IRIS 2017.

Helo, P., Gunasekaran, A., and Rymaszewska, A. (2017) 'Servitization: Service Infusion in Manufacturing', Designing and Managing Industrial Product-Service Systems', in Helo, Gunasekaran and Rymaszewska (eds.) Designing and Managing Industrial Product-Service Systems, Springer.

Höchtl, J., Parycek, P., & Schöllhammer, R. (2016). Big data in the policy cycle: Policy decision making in the digital era. Journal of Organizational Computing and Electronic Commerce, 26(1–2), 147–169. https://doi.org/10.1080/10919392.2015.1125187

Hoskyns, C. & Rai, S. M. (2007) 'Recasting the Global Political Economy: Counting Women's Unpaid Work', NPE12 (3), 297-317.

Huhtamäki, J., Basole, R., Still, K., Russell, M., & Seppänen, M. (2017). Visualizing the Geography of Platform Boundary Resources: The Case of the Global API Ecosystem. In Proceedings of the 50th Hawaii International Conference on System Sciences (HICSS). https://doi.org/10125/41804

Huhtamäki, J., Lasrado, L., Menon, K., Kärkkäinen, H., & Jussila, J. (2015). Approach for Investigating Crowdfunding Campaigns with Platform Data: Case Indiegogo. In Proceedings of the 19th International Academic Mindtrek Conference (pp. 183–190). Tampere, Finland: ACM. http://dx.doi.org/10.1145/2818187.2818289

Huhtamäki, J., Russell, M. G., Rubens, N., & Still, K. (2015). Ostinato: The Exploration-Automation Cycle of User-Centric, Process-Automated Data-Driven Visual Network Analytics. In S. A. Matei, M. G. Russell, & E. Bertino (Eds.), Transparency in Social Media: Tools, Methods and Algorithms for Mediating Online Interactions (pp. 197–222). Springer International Publishing Switzerland. https://doi.org/10.1007/978-3-319-18552-1_11

Huotari, P., Järvi, K., Kortelainen, S., & Huhtamäki, J. (2017). Winner does not take all: Selective attention and local bias in platform-based markets. Technological Forecasting and Social Change, 114, 313–326. https://doi.org/10.1016/j.techfore.2016.08.028

Intven, H. (2000). Telecommunications Regulation Handbook Module 1 Overview of Telecommunications Regulation edited by. Retrieved from https://www.itu.int/ITU-D/treg/Documentation/Infodev_handbook/1_overview.pdf

ITU, (2012). Impact of broadband on the economy, broadband series regulatory & market environment.

ITU, (2018). The economic contribution of broadband, digitization and ICT regulation Expert reports Thematics ITU Publications. Retrieved from https://www.itu.int/en/ITU-D/Regulatory-Market/Documents/FINAL_1d_18-00513_Broadband-and-Digital-Transformation-E.pdf

Jacobides, M., (2019). Designing digital ecosystems in Platforms and Ecosystems: Enabling the Digital Economy, Briefing Paper, World Economic Forum. Online:

Järvi, K., & Kortelainen, S. (2017). Taking stock of empirical research on business ecosystems: a literature review. International Journal of Business and Systems Research, 11(3), 215–228.

Jensen, R. (2007). "The Digital Provide: Information (Technology), Market Performance, and Welfare in the South Indian Fisheries Sector". Quarterly Journal of Economics, 122(3), 879-924.

Kahan, Marcel and Klausner, Michael D. (1997). Standardization and Innovation in Corporate Contracting (or 'the Economics of Boilerplate'). Virginia Law Review, Vol. 83, No. 4, 1997. Available at SSRN: https://ssrn.com/abstract=10522

Kahneman, D. (2011). Thinking, Fast and Slow, New York, NY: Farrar, Straus and Giroux.

Kallis, G., Gómez-Baggethun, E., and Zografos, C. (2013) 'To value or not to value? That is not the question', Ecological Economics 94, 97–105.

Karner, J and Onyeji, R. (2007). Telecom Private Investment and Economic Growth: the case of African and Central & East European Countries. Jonkoping International Business School

Katz, R. (2011). "The impact of broadband on the economy: research to date and policy issues", Trends in Telecommunication reform 2010-11. Geneva: International Telecommunication Union.

Katz, R. (2015). La economía y el ecosistema digital en América Latina. Madrid: Ariel.

Katz, R. , Vaterlaus, S., Zenhäusern, P. and Suter, S. (2012). "The Impact of Broadband on Jobs and the German Economy". Intereconomics, 45 (1), 26-34.

Katz, R. and Berry, T. (2014). Driving demand for broadband services. London: Springer. Katz, R. and Callorda, F. (2014). Assessment of the Economic Impact of Telecommunications in Senegal (2003-2014). Columbia Institute for Tele-information Working Paper.

Katz, R. and Koutroumpis, P. (2012a). The economic impact of broadband on the Philippines. Geneva: International Broadband Commission.

Katz, R. and Koutroumpis, P. (2012b). "The economic impact of telecommunications in Senegal", Digiworld Economic Journal, no. 86, 2nd Q. Katz, R. and Koutroumpis, P. (2013a). "Measuring digitization: a growth and welfare multiplier".

Katz, R. and Suter, S. (2009). Estimating the economic impact of the broadband stimulus plan. Presentation at the National Press Club, Washington, DC.

Katz, R., & Callorba, F. (2018). The economic contribution of broadband, digitization and ICT regulation Expert reports Thematics ITU Publications. Retrieved from https://www.itu.int/en/ITU-D/Regulatory-Market/Documents/FINAL_1d_18-00513_Broadband-and-Digital-Transformation-E.pdf

Katz, R., Koutroumpis, P. and Callorda, F. (2013b), "The Latin American path towards digitization". Info, Vol. 15, No. 3, pp. 6-24. Katz, R., Koutroumpis, P. and Callorda, F. (2014). "Using a digitization index to measure the economic and social impact of digital agendas".

Kavassalis, P., Stieber, H., Breymann, W., Saxton, K. and Gross, F. (2018), "An innovative RegTech approach to financial risk monitoring and supervisory reporting", Journal of Risk Finance, Vol. 19 No. 1, pp. 39-55. https://doi.org/10.1108/JRF-07-2017-0111

Kleinrock, L., "Information Flow in Large Communication Nets," Ph.D. Thesis Proposal, Massachusetts Institute of Technology, May 1961.

Kuhn, T. S. (1962). The structure of scientific revolutions, University of Chicago Press.

Kuznets, S., (1934). "National Income, 1929–1932". 73rd US Congress, 2d session, Senate document no. 124, page 7.

La Torre, M., Botes, V. L., Dumay, J., Rea, M. A., & Odendaal, E. (2018). The fall and rise of intellectual capital accounting: new prospects from the Big Data revolution. Meditari Accountancy Research, 26(3), 381–399. https://doi.org/10.1108/MEDAR-05-2018-0344

Lazer, D., Pentland, A., Adamic, L., Aral, S., Barabási, A.-L., Brewer, D., … Alstyne, M. Van. (2009). Computational Social Science. Science, 323(5915), 721–723. https://doi.org/10.1126/science.1167742

Leiner, Barry & Cerf, Vinton & Clark, David & Kahn, Robert & Kleinrock, L. & Lynch, Daniel & Postel, Jonathan & Roberts, Lawrence & Wolff, Stephen. (2009). A Brief History of the Internet. Computer Communication Review. 39. 22-31. 10.1145/1629607.1629613.

Lemley, M. A., and McCreary, A. (2019), Exit Strategy, Stanford Law and Economics Olin Working Paper #542. Ibid, page 57, Available at SSRN: https://ssrn.com/abstract=3506919.

Lerner, J. and J. Tirole (2005), 'The Economics of Technology Sharing: Open Source and Beyond', Journal of Economic Perspectives—Volume 19, Number 2—Pages 99–120.

Lessig, L. (2000). Code Is Law. from Harvard Magazine website: https://www.harvardmagazine.com/2000/01/code-is-law-html

Li, W C Y, M Nirei, and K Yamana (2019), "Value of Data: There's No Such Thing as a Free Lunch in the Digital Economy", RIETI discussion paper 19-E-022.

Libert, B., & Beck, M. (2016), GDP Is a Wildly Flawed Measure for the Digital Age, Harvard Business Review.

Libert, B., & Beck, M. (2016), The Network Imperative: How to Grow Survive and Grow in the Age of Digital Business Models, Harvard Review Business Press.

Liu, Y.-Y., Slotine, J.-J., & Barabási, A.-L. (2011). Controllability of complex networks. Nature, 473(7346), 167–173. https://doi.org/10.1038/nature10011

Lord, P., Macdonald, A., Lyon, L., & Giaretta, D. (2004). From Data Deluge to Data Curation. In Journal of Documentation (Vol. 67, pp. 214–237). Nottingham, UK. http://citeseerx.ist.psu.edu/viewdoc/summary?doi=?doi=10.1.1.111.7425

Mell, P., Grance, T. (2011). The NIST Definition of Cloud Computing (Technical report). National Institute of Standards and Technology: U.S. Department of Commerce. doi:10.6028/NIST.SP.800-145. Special publication 800-145.

Moilanen, J., Niinioja, M., Seppänen, M., & Honkanen, M. (2019). API Economy 101. Books on Demand.

Monbiot, G. (2012). Putting a price on the rivers and rain diminishes us all. *The Guardian*, 6 August 2012.

Moore, James F. (1999), Predators and prey: A new ecology of competition. Harvard Business Review. pp. 75–86.

Nachira F., Nicolai A., Dini P., Le Luoarn M. and Rivera Leon L. (2007), Digital Business Ecosystems, European Commission, Bruxelles.

Nachira, F. (2002). Toward a network of digital business ecosystems fostering the local development, http://www.digital-ecosystems.org/refs/2002_dbe_discussionpaper.pdf

Nadeem, M., Dumay, J., & Massaro, M. (2019). If You Can Measure It, You Can Manage It: A Case of Intellectual Capital. Australian Accounting Review, 29(2), 395–407. https://doi.org/10.1111/auar.12227

Nakamoto, S. (2008), Bitcoin: A peer-to-peer electronic cash system, White Paper.

Neubauer J., Steffen B. (2013) Second-Order Servification. In: Herzwurm G., Margaria T. (eds) Software Business. From Physical Products to Software Services and Solutions. ICSOB 2013. Lecture Notes in Business Information Processing, vol 150. Springer, Berlin, Heidelberg

Nykänen, O., Salonen, J., Haapaniemi, M., & Huhtamäki, J. (2008). A Visualisation System for a Peer-to-Peer Information Space. In Proceedings of OPAALS 2008, 7-8 October 2008, Tampere, Finland (pp. 76–85). Tampere, Finland: Tampere University of Technology. http://urn.fi/URN:NBN:fi:tty-201104153766

OECD Statistics Working Paper, 2017/09, http://dx.doi.org/10.1787/a8e751b7-en

Oh, D.-S., Phillips, F., Park, S., & Lee, E. (2016). Innovation ecosystems: A critical examination. Technovation, 54, 1–6. https://doi.org/10.1016/j.technovation.2016.02.004

ONS (2016a) 'Women shoulder the responsibility of 'unpaid work' –costs 1.1 trillion',http://visual.ons.gov.uk/the-value-of-your-unpaid-work/

Pacioli, L. (1494), Summa de arithmetica, geometria, proportioni et proportionalita.

Parker, G. G., Van Alstyne, M. W., & Choudary, S. P. (2016). Platform Revolution: How Networked Markets Are Transforming the Economy – and How to Make Them Work for You (1 edition). New York: W. W. Norton & Company.

Parker, G., Van Alstyne, M., Jiang, X., 2017. Platform ecosystems: how developers invert the firm. MIS Q Forthcoming.

Pentland, A. (Sandy). (2019). Human-AI Decision Systems. Cambridge, MA. https://connection.mit.edu/sites/default/files/publication-pdfs/Human-AI Decision Systems.pdf

Pentland, A. "Sandy." (2015). Social Physics: How Social Networks Can Make Us Smarter. New York, New York, USA: Penguin Books.

Radio Conferences. (2019). Retrieved November 20, 2019, from Itu.int website: https://www.itu.int/en/history/Pages/RadioConferences.aspx?conf=4.37

Ranftler, D. (2016). Human-robot interaction and the four-sides-model by F. Schulz von Thun.https://blog.rwth-aachen.de/designthinking/2016/01/22/human-robot-interaction-and-the-four-sides-model-by-f-schulz-von-thun/

Reinsel, D., Gantz, J., Rydning J. (2018) The Digitization of the World - From Edge to Core., An IDC White Paper – #US44413318, Sponsored by Seagate, https://www.seagate.com/files/www-content/our-story/trends/files/idc-seagate-dataage-whitepaper.pdf

Rhodes R. (1996) "The New Governance: Governing Without Government", in Political Studies, 44(4):652–667.

Ritala, P., & Almpanopoulou, A. (2017). In defense of 'eco' in innovation ecosystem. Technovation, 60–61, 39–42. https://doi.org/10.1016/j.technovation.2017.01.004

Ritala, P., & Hallikas, J. (2011). Network position of a firm and the tendency to collaborate with competitors – a structural embeddedness perspective. International Journal of Strategic Business Alliances, 2(4), 307–328. https://doi.org/10.1504/IJSBA.2011.044859

Ritala, P., & Phillips, M. (n.d.). A complex adaptive systems agenda for ecosystem research methodology. Technological Forecasting & Social Change.

Rohlfs, J. (1974), A theory of interdependent demand for a communications

Rohlfs, J. (2003) Bandwagon effects in high-technology industries. MIT Press.

Roth, F. (2019): Revisiting Intangible Capital and Labour Productivity Growth, 2000-2015: Accounting for the Crisis and Economic Recovery in the EU, Hamburg Discussion Papers in International Economics, No. 3.

Russell, M. G., Huhtamäki, J., Still, K., Rubens, N., & Basole, R. C. (2015). Relational Capital for Shared Vision in Innovation Ecosystems. Triple Helix: A Journal of University-Industry-Government Innovation and Entrepreneurship, 2(1), 36. https://doi.org/10.1186/s40604-015-0017-2

Russell, M. G., Still, K., Huhtamäki, J., Yu, C., & Rubens, N. (2011). Transforming Innovation Ecosystems through Shared Vision and Network Orchestration. In Proceedings of Triple Helix IX International Conference: "Silicon Valley: Global Model or Unique Anomaly?", July 2011, Stanford, California, USA (p. 17). Stanford, California, USA.

Russell, S. (2019), Human Compatible: Artificial Intelligence and the Control Problem, Allen Lane

Salonen, J., Huhtamäki, J., & Nykänen, O. (2013). Challenges in Heterogeneous Web Data Analytics - Case Finnish Growth Companies in Social Media. In 17th International Academic MindTrek Conference 2013: "Making Sense of Converging Media", October 1-3, Tampere, Finland (pp. 131–138). ACM. http://urn.fi/URN:NBN:fi:tty-201312191527

Schilling, M. A. (2009). Understanding the Alliance Data. Strategic Management Journal, 30(3), 233–260. https://doi.org/10.1002/smj.731

Schreyer, P., & Zinni, B. (2018). STATISTICS AND DATA DIRECTORATE Cancels & replaces the same document of Productivity measurement, R&D assets and mark-ups in OECD countries. Retrieved from http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=SDD/DOC(2018)6&doc Language=En

Sel, M., Diedrich, H., Demeester, S., & Stieber, H. A. (2017). How Smart Contracts Can Implement "Report Once." SSRN Electronic Journal. https://doi.org/10.2139/ssrn.3111508

Shapiro, C. & Varian, H. R. (1998). Information Rules. Harvard Business School

Shapiro, C. and Katz, M. (1994), Systems competition and network effects.

Silver, N. (2012). The Signal and the Noise: Why So Many Predictions Fail-but Some Don't. Penguin. https://books.google.fi/books?id=SI-VqAT4_hYC

Smith, B., Browne C.A. (2019), Tools and Weapons: The Promise and the Peril of the Digital Age, Penguin Publishing Group, 2019, ISBN 1984877712, 9781984877710

Smith, M. A., Himelboim, I., Rainie, L., & Shneiderman, B. (2015). The Structures of Twitter Crowds and Conversations. In S. A. Matei, M. G. Russell, & E. Bertino (Eds.), Transparency in Social Media: Tools, Methods and Algorithms for Mediating Online Interactions (pp. 67–108). Springer International Publishing. http://link.springer.com/chapter/10.1007/978-3-319-18552-1_5

Soramäki, K., Bech, M. L., Arnold, J., Glass, R. J., & Beyeler, W. E. (2007). The topology of interbank payment flows. Physica A: Statistical Mechanics and Its Applications, 379(1), 317–333. https://doi.org/10.1016/J.PHYSA.2006.11.093

Soramäki, K., Cook, S., & Laubsch, A. (2016). A network-based method for visual identification of systemic risks. Journal of Network Theory in Finance, 2(1), 67–101.

Star S.L. (1999) "The Ethnography of Infrastructure", in American Behavioural Scientist, 43(3):377-391.

Star S.L. (2002) "Infrastructure and Ethnographic Practice. Working with the Fingers", in Scandinavian Journal of Information Systems, 14(2):107-122.

Star S.L. and Griesemer J.G. (1989) "Institutional Ecology, 'Translations' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39"; in Social Studies of Science, 19: 287-420.

Star S.L. and Ruhleder K. (1996) "Steps Toward an Ecology of Infrastructures: Design and Access for Large Information Spaces"; in Information Systems Research, 7(1):111-134.

Stiglitz, J., Sen, A., & Fitoussi, J. P. (2009) Report by the commission on the measurement of economic performance and social progress, available here: http://ec.europa.eu/eurostat/documents/118025/118123/Fitoussi+Commission+report

Still, K., Huhtamäki, J., & Russell, M. G. (2013). Relational Capital and Social Capital: One or two Fields of Research? In Proceedings of the 10th International Conference on Intellectual Capital, Knowledge Management and Organisational Learning, The George Washington University, Washington, DC, USA, 24-25 October 2013 (pp. 420–428).

Still, K., Huhtamäki, J., Russell, M. G., & Rubens, N. (2012). Paradigm shift in innovation indicators: from analog to digital. In Proceedings of the 5th ISPIM Innovation Forum, 9-12 December, 2012, Seoul, Korea (p. 14). Seoul, Korea.

Stockinger, K. & Braschler, M. and Stadelmann, T. (2019). Lessons Learned from Challenging Data Science Case Studies. 10.1007/978-3-030-11821-1_24.

Sturgeon, T. J. (2013). Global Value Chains and Economic Globalization - Towards a New Measurement Framework.

Suchman, M. (2003), The Contract as Social Artifact. Law & Society Review. 37. 91 - 142. 10.1111/1540-5893.3701003.

Sveiby K.E. & al. (1989): Den osynliga balansräkningen (The Invisible Balance Sheet), Ledarskap Stockholm.

Sveiby, K.E. (1998). Measuring Intangibles and Intellectual Capital - An Emerging first Standard.

Szabo N. (1994), Smart contracts in Essays on Smart Contracts, Commercial Controls and Security <http://szabo.best.vwh.net/smart.contracts.html >

Szabo, N. (1997). Formalizing and Securing Relationships on Public Networks. First Monday. 2. 10.5210/fm.v2i9.548.

Tapscott, D., Tapscott, A. (2016) Blockchain Revolution, Penguin, New York.

Telecommunications Regulation Handbook 117. (n.d.). Retrieved from http://www.infodev.org/sites/default/files/resource/InfodevDocuments_1068.pdf

Telesca, L., Hazard J. (2020), From Legal Prose to Code: Restructuring Contract Templates for Blockchain Automation, The LegalTech Book: The Legal Technology Handbook for Investors, Entrepreneurs and FinTech Visionaries, Wiley; 1 edition, In press.

Triantis, G. G. (2013), Improving Contract Quality: Modularity, Technology, and Innovation in Contract Design (July 29, 2013). Stanford Journal of Law, Business, and Finance, Vol. 18, No. 2; Stanford Public Law Working Paper No. 2306209; Stanford Law and Economics Olin Working Paper No. 450. Available at SSRN: https://ssrn.com/abstract=2306209

Varian, Hal R., Use and Abuse of Network Effects (September 17, 2017). Available at SSRN: https://ssrn.com/abstract=3215488

Watts, D. J. (2013). Computational Social Science: Exciting Progress and Future Directions. The Bridge, 43(4), 5–10.

Wikipedia Contributors. (2019a, November 5). International Telecommunication Union. Retrieved November 18, 2019, from Wikipedia website:

Wikipedia Contributors. (2019b, November 5). Telephone exchange. Retrieved November 18, 2019, from Wikipedia website:

Wikipedia. (2018, September 7). Telco-OTT. Retrieved November 20, 2019, from Wikipedia website: https://en.wikipedia.org/wiki/Telco-OTT

Wright, A., & De Filippi, P. (2015). Decentralized Blockchain Technology and the Rise of Lex Cryptographia. SSRN Electronic Journal.

WTO Reference Paper. (2019). Retrieved November 18, 2019, from Itu.int website: https://www.itu.int/newsarchive/press/WTPF98/WTORefpaper.html

Xu X., Weber I., and Staples M. (2019). Architecture for Blockchain Applications, Springer, 2019

Xu, X., Pautasso, C., Zhu, L., Lu, Q., & Weber, I. (2018). A Pattern Collection for Blockchain-based Applications. In Proceedings of the 23rd European Conference on Pattern Languages of Programs - EuroPLoP '18 (pp. 1–20). New York, New York, USA: ACM Press. https://doi.org/10.1145/3282308.3282312

Zheng, Zibin & Xie, Shaoan & Dai, Hong-Ning & Chen, Xiangping & Wang, Huaimin. (2018). Blockchain challenges and opportunities: A survey. International Journal of Web and Grid Services. 14. 352. 10.1504/IJWGS.2018.095647.

Zittrain, Jonathan, 'Chapter 45 - Internet' from A History of IP in 50 Objects (April 16, 2019). A History of Intellectual Property in 50 Objects, Cambridge University Press, Jun 2019; ISBN 9781108420013. Available at SSRN: https://ssrn.com/abstract=3373352

6. Online resources

https://www.Internethalloffame.org/brief-history-Internet#Transition
http://global-perspectives.org.uk/wp-content/uploads/2017/10/making-the-future-count.pdf
http://ide.mit.edu/sites/default/files/publications/SSRN-id3356697%20gdp2.pdf
http://www.jstor.org/stable/25758526
http://www3.weforum.org/docs/WEF_Digital_Platforms_and_Ecosystems_2019.pdf
https://en.wikipedia.org/wiki/International_Telecommunication_Union
https://en.wikipedia.org/wiki/Telephone_exchange
https://hbr.org/2016/07/gdp-is-a-wildly-flawed-measure-for-the-digital-age
https://hbr.org/2019/11/how-should-we-measure-the-digital-economy
https://www.ecb.europa.eu/paym/groups/pdf/omg/2017/201710/2017-10-05_OMG_Item_2_Regulatory_technologies.pdf?75128c49931f23551cf42cc14604a3fe
https://www.ecb.europa.eu/pub/economic-bulletin/focus/2018/html/ecb.ebbox201807_03.en.html
https://www.itu.int/ITU-D/treg/broadband/ITU-BB-Reports_Impact-of-Broadband-on-the-Economy.pdf
https://www.nae.edu/File.aspx?id=106114%5Cnpapers3://publication/uuid/76B40E1B-5E82-4E23-9DAD-97A318DC7DE9
https://www.sciencedirect.com/book/9780750677745/making-sense-of-intellectual-capital
https://www.accessnow.org/ott-vs-telecom-services/
http://szabo.best.vwh.net/smart.contracts.html
https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=LEGISSUM%3Al24108j
http://aeaweb.org/articles?id=10.1257/jep.8.2.93
http://global-perspectives.org.uk/wp-content/uploads/2017/10/making-the-future-count.pdf
http://global-perspectives.org.uk/wp-content/uploads/2017/10/making-the-future-count.pdf
http://ide.mit.edu/sites/default/files/publications/SSRN-id3356697%20gdp2.pdf
http://ide.mit.edu/sites/default/files/publications/SSRN-id3356697%20gdp2.pdf
http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=SDD/DOC(2018)6&docLanguage=En
https://hbr.org/2016/07/gdp-is-a-wildly-flawed-measure-for-the-digital-age
https://hbr.org/2019/11/how-should-we-measure-the-digital-economy
https://hicss.hawaii.edu/tracks-53/organizational-systems-and-technology/#managing-the-dynamics-of-platforms-and-ecosystems-minitrack
https://www.ecb.europa.eu/pub/economic-bulletin/focus/2018/html/ecb.ebbox201807_03.en.html
https://ec.europa.eu/growth/single-market/european-standards_en
https://www.ecb.europa.eu/paym/groups/pdf/omg/2017/201710/2017-10-05_OMG_Item_2_Regulatory_technologies.pdf?75128c49931f23551cf42cc14604a3fe
https://ec.europa.eu/newsroom/just/item-detail.cfm?item_id=638348
http://www.commonaccord.org/index.php?action=list&file=G/
http://schema.org
http://openscience.adaptcentre.ie/projects/GDPRtEXT/
http://openscience.adaptcentre.ie/GDPR-checklist-demo/demo/
https://data.gov.ie/dataset/suggest/a5f365f6-719f-4eab-9bfe-4d494aeb31ee
https://github.com/matomo-org/matomo/issues/12805
https://www.actus-protocol.io/
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DS-04-20-084-EN-N

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doi: 10.2838/28184