

Elements Related to Maturity of Function in Markets

An Initial Exploration of the Applicability of Market Mechanisms
for Solving Challenges in the Information Environment

R.J. Cordes

March 3, 2022

Version 1.1

Abstract:

Market mechanisms and market-informed approaches have been suggested to address the current dire state of our global information environment. Markets certainly can be effective mechanisms for decentralized coordination, but it is equally true that under certain conditions they begin to degrade in terms of their ability to convert self-interest into collective utility. As markets mature over time, in terms of the efficacy and appropriateness of function in relation to their current interaction volume, new pressures are placed on certain elements of their operations - generating emergent solutions and restructuring. Some aspects of both these emergent solutions and the market mechanisms which generate them may be of value to analogous challenges in the information environment. In this paper, markets are generalized under an operational definition using fuzzy set theory, and a proposed set of 8 elements related to the development of markets over time are explored, with consideration for market-like structures captured by the operational definition. The usefulness of these 8 elements and next steps for investigation into the applicability of market mechanisms for solving challenges in the information environment are discussed.

Keywords: Markets, Market Design, Mechanism Design, Reputation Management Systems, Economic History, Social Systems Engineering, Commercial Law

Introduction

In response to the current low-trust, volatile state of the global information environment, market and market-informed approaches have been suggested as a remedy. This is done on the basis that, historically, markets have had and solved fundamental challenges such as difficulty in mapping and accommodating buyers and sellers (liquidity), maintaining reliability in terms of exchange outcomes (standards), providing recourse in the case expectations of exchange outcomes are not met (recourse), and creating the institutions necessary to constitute coherent, synthetic intelligence, all of which constitute challenges of trust and authenticity which are analogous to underlying problems in the information environment [1]. Markets can be reasonably described as an effective mechanism for the coordination of activity and allocation of resources at scale [2], however, it also equally true that markets alone, without market design interventions will, at some point in their development, begin to degrade in terms of their ability to provide system- rather than actor-level utility [3] in the way that other social systems engineering informed coordination mechanisms are intended to [4].

In order to consider the use of market mechanisms for solving problems of trust and authenticity in the information environment it is necessary to be able to describe markets in terms of their relative level of maturity, or efficacy and appropriateness of function in relation to their current interaction volume, in order to better understand at what stages and on what foundations they create the conditions for emergence of liquidity, standards, and recourse related solutions. In addition, it is important to be able to understand at what stages they begin to decrease in value as a mechanism. Further, if the intent is to apply market mechanisms in a system which does not appear to be a market as it would traditionally be defined, there is an apparent need to provide a definition of markets, and consequently, of exchange, which encompasses non-traditional markets. This, unfortunately, requires a new approach, as it would appear that finding a definition of market which is sufficient to effectively describe the myriad phenomena and structures which would already be considered markets is a challenge in and of itself [5].

In this paper, there is an operational approach toward defining markets through the use of fuzzy set theory and a precursory definition of exchange. The applicability of this approach in describing myriad market-like structures and phenomena, commercial and otherwise, is then considered. Next, the development of markets is investigated through the use of common “elements” found in traditional markets, with consideration for their analogs in other market-like structures covered under a fuzzy definition of markets. Finally, these elements are briefly discussed in terms of their relationship to information markets.

Toward a General Definition of Markets

Exchange

Those with some familiarity of modern markets might associate the concept of exchange with “that which occurs in an exchange house”, such as a securities or currency exchange. Those with a familiarity of the history of markets might instead primarily associate exchange with a broader set of trading phenomena, from the birth of ancient East Asian and Mediterranean trading routes to the highly complicated financial systems of today. However, exchange can and has been interpreted as a far more fundamental and general phenomenon. The 19th Century social philosopher Georg Simmel, in his 1900 magnum opus, “Philosophy of Money”, within a section titled “Exchange as a Form of Life”, states:

“It should be recognized that most relationships between people can be interpreted as forms of exchange. Exchange is the purest and most developed kind of interaction, which shapes human life when it seeks to acquire substance and content. It is often overlooked how much what appears at first a one-sided activity is actually based upon reciprocity...”

[6]

Nietzsche, in his 1887 book “Genealogy of Morals”, goes further than Simmel, stating:

“Setting prices, determining values, contriving equivalences, exchanging - these preoccupied the earliest thinking of man to so great an extent that in a certain sense they constitute thinking as such: here it was the oldest kind of astuteness developed... man designated himself as the creature that measures values, evaluates and measures, as the “valuing animal as such”. Buying and selling, together with their psychological appurtenances, are older even

than the beginnings of any kind of social forms of organization and alliances: it was rather out of the most rudimentary form of personal legal rights that the budding sense of exchange, contract, guilt, right, obligation, settlement, first transferred itself to the coarsest and most elementary social complexes (in their relations with other similar complexes), together with the custom of comparing, measuring, and calculating power against power."

[7]

This more fundamental view of exchange and related analyses as underpinning human behavior has since been explored further and become more widely accepted, with biologists and anthropologists recognizing exchange between non-kin as a "hallmark" of human sociality as "ancient as the genus Homo" [8] and including abstract interactions such as providing access to mates, ideas, and future reciprocation within the scope of exchange [8–10]. For example, the choice of early humans to cohabitate becomes an exchange of potential opportunities to observe innovations - the choice to share, as Simmel suggested, becomes an exchange of goods and benefits in the short-term for the potential of future reciprocity in the long-term. Even where the choice to share is explicitly accompanied by an expressed disinterest in reciprocation, an abstract exchange could still be argued to have occurred - for example, when giving to a charity, an individual expends resources and receives abstract benefits related to mental well-being and social standing.

This view of exchange as fundamental to human interaction does not mean exchange is exclusive to human-to-human interaction. Simmel argues that even where one makes short term sacrifices for long term gain, these abstract cases are not analogous to exchange between individuals, but instead *the fundamental essence of what constitutes exchange generally* [6], "the willingness to sacrifice one thing for another" [11]. Further, this view does not mean exchange is exclusive to humans, as animals can

participate in exchange with humans for tangible short term benefits [12], analyze and respond to disparity in exchange rate and quality [13], and even participate in the kinds of abstract exchanges humans do, with or without conscious acknowledgement of the exchange itself or of its value. For example, lycaenid caterpillars providing nectar to ants in exchange for protection [14], or kingfishers feeding non-kin nestlings which may improve chances of mating in the future [15]. In both cases, expectation of return is embodied in action.

In this context, exchange becomes quite general while still holding value for use in a variety of fields. For our purposes, exchange can thus be defined as:

Exchange. *To expend or offer a tangible or intangible service, object, option, or benefit with expressed or embodied expectation of return.*

Markets

The definition of exchange offered above begs the question of how to define a market. Unlike the concept of an exchange, which can be defined as a mechanism at all levels of analysis, markets can carry connotations of mechanism, physical and quasi-physical space (e.g. a digital environment), set or collection, or concept at any level of analysis - making them far more difficult to define [5]. Within the scope related to any of these connotations, there is also the difficulty of ensuring scale- and approach-agnostic definitions, for example, being able to simultaneously account for a market as defined by market segmentation (e.g. in marketing and sales at local, national, or international) [16], national level economies [17], markets “as the socio-economic phenomenon which takes place in the marketplace”, or the location of that socio-economic phenomenon, whether it be a building, a cluster of buildings, a province, or a website [5,18]. Further, just like exchange, markets have long been used as abstractions to scope categories and collections of exchanges outside of commerce, in everything from sports regulations [3] to biology [15]. Across all of these

approaches and connotations, there appears to be at least one commonality: that each relates to collections of expectations related to exchange, and as such, a mathematical structure known as a “fuzzy set” may be of use in providing a definition which is both sufficiently rigorous and general enough for our purposes.

Set Theory

Set theory is the mathematical logic that is concerned with “sets”, or more simply, collections of elements. The term element used here is very general, such that a set could be a collection of variables, numbers, objects, or even other sets, as well as empty sets in which no elements are contained. Elements can belong to more than one set (leading to intersections between sets), but it is always binary whether they have membership in a given set or not. There is no measure for ambiguity of element inclusion in traditional set theory. However “more often than not, the classes of objects encountered in the real physical world do not have precisely defined criteria of membership... yet, the fact remains that such imprecisely defined ‘classes’ play an important role in human thinking, particularly in the domains of pattern recognition, communication of information, and abstraction” [19].

Fuzzy Sets

The real-world ambiguities of class membership paired with the limitations on representation of class membership in set theory motivated the creation of a new approach: “fuzzy sets” [19]. Fuzzy sets are a generalization of sets which introduces a continuum of *grades* of membership. “Such a set is characterized by a membership (characteristic) function which assigns to each object a grade of membership ranging between zero and one” [19]. This allows for object classes outside the context of mathematical formalism and software engineering to be more rigorously defined. A simple illustrative example might be the capability to move from the ‘set of all numbers greater than 5’ to the ‘fuzzy set of all numbers *much* greater than 5’.

Like ordinary set theory, the fuzzy set formalism is scale-agnostic in terms of the system it intends to represent given that sets may be contained within other sets without necessarily instituting hierarchical organization, allowing for the representation of systems and subsystems of any scale. While some aspects of traditional set theory are approach-agnostic given their generality, fuzzy sets are especially approach-agnostic due to the capacity to represent an element's class membership in terms of either their likelihood of belonging or as their degree of belonging. Most importantly, as previously stated, this membership function of a fuzzy set addresses the ability to represent ambiguity in class membership in myriad systems where the lack of binary membership is either useful or unavoidable. These three properties of fuzzy sets have led to its broad application in areas such as data processing, decision support systems, management and logistics, medicine, graph theory, control theory, topology, operations research, and natural language processing [20,21]. Further, these three properties have made it valuable to both the social sciences and economics, where ambiguity in class membership in terms of human expectations would otherwise create limitations on quantitative approaches [22]. For the same reasons that fuzzy set theory is "particularly well suited as a bridge between natural language and formal models" [20], it is also well suited as a bridge between the social construction of what constitutes a market and the necessary formality of market definition.

For example, a collection (a set) of objects and benefits represented as the aggregate of expectations of potential market participants about the likelihood of being able to engage in exchange of those objects and benefits, constitutes a market definition of a given environment superior to that of simple binary segmentation, especially where markets are in early stages of development (e.g. barter markets [23]). With the use of more specific conditions and formulae for measuring class membership and the use of fuzzy set operators, such as unions and intersections (See "Fuzzy Sets" by Lofti Zadeh [19], for more information on these operations and the differences between their

uses in set and fuzzy set theory), these fuzzy sets can in turn become higher resolution and more descriptive. For example, the intersection of:

- a set of objects and benefits represented as the aggregate of expectations of potential buyers (a set of individuals who have expectations about being able to make purchases related to the environment) about the likelihood of being able to *purchase* those objects and benefits (A), where expectations are valued at greater than 0.75 and
- a set of objects and benefits represented as the aggregate of expectations of potential sellers (a set of individuals who have expectations about being able to make sales related to the environment) about the likelihood of being able to *sell* those objects and benefits (B), where expectations are valued at greater than 0.75,

$$A \cap B = C$$

would represent a formal definition of a given market in terms which might be highly comparable with those we would find in linguistic terms (e.g. a fish market, or a book store) while also being consistent with what we might expect in terms of liquidity associated with any of the objects and benefits. This is not to say that a fuzzy set represents a *model* of the market. Instead, fuzzy sets as-market-definition could be functional outputs from institutional, system, and cognitive models of the market which take into account norms, standards, narrative, and other factors which affect the perception and collective construction of what constitutes a market without complicating the expression of its definition [24,25]. Further, nested sets of categories of products and derivatives of products, or aggregate expectations weighted based on fuzzy sets of participants or institutions sets might be operated on in order to define other aspects of markets and their interconnections, and could consist of a variety of conditions and metrics for membership beyond expectation of opportunity for exchange.

Markets

With the use of the preceding definitions of exchange and fuzzy sets, and the acknowledgement of the need for a definition which captures the spirit of the myriad definitions of markets while remaining scale- and system-agnostic, we can define a market as:

Market. *An environment with any composition of systems, infrastructure, or norms, about which agents have real or embodied expectations of exchange regarding a fuzzy set of tangible or intangible services, objects, options, or benefits.*

In simple terms, markets can be seen as *exchange environments* that can act as mechanisms; with the designation-as-market being created from the collection of *fuzzy* expectations about that environment being useful for exchange. These expectations are *fuzzy* because they vary from individual to individual, change based on feedback, and, given that these expectations live in the minds of actors and observers, are very difficult to quantify. However, regardless of how *fuzzy* these expectations are, they are still real. For example, it is rare that one goes to a book store without embodying expectations about potential exchange [26]. As further clarification, under this definition, both the book store and the town in which it resides constitute equally valid examples of a market related to books, with one offering a much higher likelihood of the ability to purchase or sell books than the other - and this is the case whether or not individuals have elected to consciously consider, define, or act on these expectations. This definition also captures those markets wherein expectations are projected on the participants by observers, such as the exchange of food for security between honeydew-producing Homoptera and ants, as behavioral “choices” related to production and provision, which are influenced and embodied as though they were consciously considered [15,27].

Maturity of Market Mechanisms Over Time

Heterodox Economics

The definition of market offered above is useful because it can capture various connotations of markets in common parlance or obscure instances such as biological markets, and because it is compatible with recent systems-oriented approaches to markets. These approaches include pluralist economics [28], complexity economics [29], new institutional economics [24], and, more generally, heterodox economics [30], as well as other approaches which do not sit within a defined field, such as those which simply see markets as a general structure, unspecific to commercial activity, with proximal similarity to other adaptive, evolving structures [3]. These approaches come with their fair share of critiques, however, despite being associated with *dissent against orthodoxy*, the recognition that “economic activities are embedded in culture” [28], that markets constitute complex, adaptive, social systems [3,24,29], and that the impact, design, and analysis of market mechanisms is a meaningful challenge beyond the scope of more traditional economic models [31] are all relatively mainstream views now - with some new work in these spaces being produced by individuals associated with the economic theories that heterodox approaches are intended to replace [32]. McMillan, in his book, “Reinventing the Bazaar: A Natural History of Markets”, offers a useful, albeit unintentional, summary of many of these concepts:

“Textbook economic theory does not dispel the markets-are-magical notion... The supply and demand diagram, expounded in countless Economics 101 lectures, is a bloodless account of exchange. It leaves unexplained much of what needs to be explained. It tells us what prices can do, but is silent on how they are set. Supply and demand bypasses questions of how buyers and sellers get together, what other dealings they have, how buyers evaluate what they are buying, and how agreements are

enforced... A market is a social construction. If it is to work smoothly, it must be well built. The term market design refers to the methods of transacting and the devices that serve to allow transacting to proceed smoothly. Market design consists of the mechanisms that organize buying and selling; channels for the flow of information; state-set laws and regulations that define property rights and sustain contracting; and the market's culture, its self-regulating norms, codes, and conventions governing behavior. While the design does not control what happens in the market-as already noted, free decision-making is key - it shapes and supports the process of transacting."

[3]

As complex adaptive systems, markets have nonlinear and emergent properties, making their behavior difficult to predict. However, nonlinear and emergent are not synonymous with chaotic, complex adaptive systems have systemic tendencies [29], developmental patterns [3,33], and interaction motifs [34] expressed and moderated by component mechanisms, interactions of component entities, environmental constraints, nested and adjacent systems, and threats [34–37].

In the case of markets, or economic systems generally, constraints may be tangible constraints, such as those generally focused on in traditional economics approaches (e.g. supply, demand, and physical and quasi-physical infrastructure constraints), or intangible constraints, such as those focused on in heterodox economics approaches. These intangible constraints can be placed into two groups, formal and informal:

Formal Constraints.

- Laws
- Rules
- Rights
- Organizational Relationships and Treaties

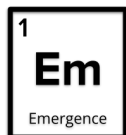
Informal Constraints.

- Taboos
- Customs
- Traditions
- Codes of Conduct
- Interpersonal Relationships

[24]

Elements of Market Development

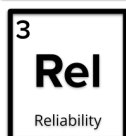
These intangible constraints coevolve with the market and the social systems within which the market is nested [29], allowing for the market to grow in terms of volume of exchange, or more broadly, in terms of interaction volume, and mature in terms of facilitating these growing interaction volumes without collapsing or splintering. This coevolution between interaction volume, intangible constraints, and relevant capabilities is argued here to be related to 8 common elements:



Emergence. The emergence of new market dynamics or behaviors based on current state and environmental conditions (e.g. the simultaneous presence of supply and demand).



Information. The ability for participants to receive, send, compress, and access information at a rate and level of quality appropriate for the complexity and volume of exchange.



Reliability. Expectations regarding the reliability of exchange outcomes and rights are commensurate with

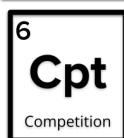
reward and risk, and are preferred relative to available alternatives.



Recourse. If expectations of an exchange outcome is not met, there is recourse available to reconcile the affected participants' relationship with the market, enforce agreements, and sanction bad-faith and negligent actors.



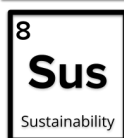
Specialization. The ability for participants to specialize within the market at a depth commensurate with demand and appropriate for the complexity and volume of exchange.



Competition. The market has sufficient accessibility and opportunities to encourage new and old participants to innovate and adapt to capture competitive advantage.



Resiliency. Risk mitigation and supply buffering commensurate with the probability and potential impact of disruption, and complexity of the systems which facilitate, supply, and enable exchange.



Sustainability. The ability to ensure continued operations and mitigate the negative externalities market interaction creates.

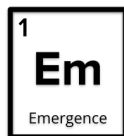
Maturity of Mechanism

As a market develops and balances these elements, it becomes more mature, or more effective for handling exchange volume and complexity [3], and acting as mechanisms for collective tasks, such as setting prices, allocating resources, and directing attention [2]. While markets-as-mechanisms for collective tasks is sometimes seen as a libertarian concept, outside the context of political discourse this is a thoroughly apolitical and fundamental aspect of markets; within the context of auction theory, these “elements” might be seen as related to the efficacy of the mechanism for collective price setting and discovery [38], and within the context of collective intelligence or crowdsourcing, as elements related to the appropriateness of task delineation, task modularity, solution requirements, and feedback requirements given the number of agents in a system [4]. Within the context of work on market history and developmental cycles, the notion of market-as-mechanism sometimes serves as a useful bridge between Keynes and Hayek, as there is a necessary recognition of the usefulness of emergent, self-organizing, adaptive, and problem-solving aspects of markets while also acknowledging the necessity to nudge them through mechanism design [3].

These 8 elements are iteratively developed by actors and organizations of actors within the market [39], with each acting as a necessary foundation for others, continuously in response to new pressures of interaction complexity and volume brought on by further maturity [3]. Below, the development of markets is explored using the 8 elements and the relationships between them.

Market Development Over Time

Emergence



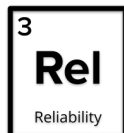
Wherever the primordial soup of demand, available or potential supply, and sufficiently low barriers to interaction exist, haphazard exchange will emerge. This is fundamentally true regardless of formal constraints, whether it is exchange of goods during Mao's agricultural reforms [3] or exchange of tobacco within jails [40]. If haphazard exchange is successful, interaction volume increases to the extent that tangible constraints and availability of information allows.

Information



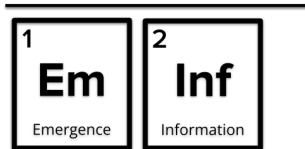
This increase to interaction volume generates new frictions for liquidity and coordination between buyers and sellers which can be expressed as information differentials. Where haphazard exchange is the norm, these information differentials represent significant opportunities for trading advantages and arbitrage - incentivizing work in routing and connection of information and finding more efficient ways to communicate. In biological markets, the limited ability for any particular generation to innovate to improve coordination is offset by evolution of signaling capabilities [15,41]. Markets whose agents are incapable of overcoming constraints on information flows fail to mature beyond haphazard exchange. Finding solutions to these information-related challenges both facilitates existing demand and invites further growth.

Reliability



As each interaction reinforces and contributes to expectations of future interactions, growth begins to place pressure on the reliability of both quality and liquidity. At the risk of offering a convenient "just-so" story: in biological markets, solutions to this pressure could be argued to appear in the development of seasonality and periodicity of cooperative behaviors, wherein species shift from haphazard chance encounters as a basis for potential mating contacts to collecting in droves at specific times

to improve liquidity and reliability of expectations, thereby reducing the often significant costs of discovery, signaling, and performing. In commerce, we see solutions appear in the form of fairs and periodic markets.



The emergence of periodic markets or submarkets as a mechanism for increasing reliability of liquidity and outcome of exchange is not just a historical phenomena - it still occurs in modern times, both in traditional and rural markets (e.g. in the barter markets of the Songola [23]) and in advanced economies (e.g. conventions, conferences, and product shows). These periodic markets create reliable liquidity while also generating opportunities for setting common norms and building trust between individuals of different groups. These norms are not exclusively cultural - for example, it is in this stage that we see the emergence of common reference-currencies and standards, the transition from haphazard valuation to standards for trade in the form of nested sub-markets, such as fish-for-rice, salt-for-soap, obligations-for-objects, or standardized cloth patterns in barter markets [23,24,42]. While these phenomena are best characterized as solutions to improve reliability of liquidity and exchange outcomes, they also act as emergent foundations for information compression and help to coordinate demand and the emergence of new actors and types of interaction.

A key case study on the impacts of, reasons for, and solutions to pressures on reliability in markets experiencing rapid increases in interaction volume is the agricultural boom of the 11th and 12th Centuries. Following the collapse of the Roman Empire, there was an extreme decline in economic activity - with some scholars going as far as to say that commercial activity was relatively "nonexistent" [43]. During this period, trade was fairly haphazard and highly constrained for a variety of reasons. Due to the presence of pirates and brigands, even the ability to get goods to a market without them being stolen was relatively uncertain [44]. However, a sudden increase in agricultural

productivity effectively reset the economy, with the reliability of availability contributing to the growth of new towns and cities, and most importantly, the emergence of traveling, periodic fairs to which, or with which, merchants could travel to with expectations of reliable liquidity [44–46]. This reliability of expectations of value and timing encouraged the provision of protections by local governments, which in turn increased reliability of expectations of the markets themselves [45].



At this level of maturity, reliability within the market allows for stable connections to other markets, placing new pressures on the development of information flow. In particular, it places pressure on the ability to map between systems of information compression. This is expressed in the numerous “pidgin” languages developed across the world. “Pidgin” is one of many terms for describing languages which serve as intermediaries between two other languages, which emerge where it is “impossible or impracticable for the peoples concern to learn each other's language” [47]. Other terms include creoles, jargons or trade-specific languages, mixed languages, *patois*, and *lingua franca*. These languages often emerge through trading encounters [47,48], and serve as an example of emergent ONFT (ontologies, narrative, formal documents, and tools) [49].

After the establishment of reliability, the market is a fundamentally different object. Whereas in previous stages, if a market failed to meet new pressures it might have simply stagnated or dissipated - now markets run this risk of “collapse”. The failure for the market to operate as expected now does demonstrable damage to its participating agents by merit of the fact that it is at this stage of maturity because it has become reliable enough for interconnection with other reliable systems - for agents and other markets to embody or plan based on expectations of its continued operation. Further, success will now mean the potential for explosive growth in interaction volume as reliability invites further interconnection with other markets and systems. This generates a feedback loop introducing new pressures on reliability and information flows.

Recourse



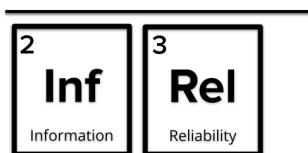
In much the same way that increased availability of foraging related communication among eusocial insects invites eavesdropping by predators of ants and those looking for a free meal [50,51], increased communication about value being exchanged creates a cascade of effects which includes both improved coordination between existing participants and a deluge of new agents - some of which will seek to exploit the system.

Complex social systems rely on reputation mechanics, whether they are based on gestural accounting in dolphins [52] or on alcohol in iron age France [53]. As groups become larger, approaching limitations of management of interpersonal relationships [54], they begin to rely on a process sometimes referred to as “identity fusion” and homophily, which is developed through ritual, shared customs, bonding, and feedback loops of communal sharing [55,56]. Identity fusion through communal sharing and distribution of surplus develops stable coalitions which help establish reliability in everything from stable trading routes to emergent militias and security retainers [53,55]. Further, the clarity of what constitutes an ingroup and its norms allows for taboos, or the breaking of those norms, to be the foundation for social sanctions and avoidance of ostracization as a means of maintaining good-faith behavior in sharing and trade [44,57,58]. Some argue that the development of “moralizing gods” preceded or even enabled the development of large trading centers, as they allowed for identity fusion and reliability in expectations of behavior using common signals of trust at a scale far beyond the limitations of the mechanisms of evolutionary psychology discussed above [59–61].



However, when markets grow to the extent that they invite “aliens”, or traders from foreign cultures, the mechanisms discussed are no longer sufficient. For example, following the development of reliability through trading fairs in Europe, interpersonal relationships, memory, and emergent norms soon failed to remain an adequate basis for honest behavior and the

trust necessary to continue trade as “transferable reputations for honesty [only serve] as an adequate bond for honest behavior if members of the trading community can be kept informed about each other’s past behavior” [44]. In other words, markets can approach this stage of maturity through emergent standards and measures to improve liquidity and expectations of exchange outcomes, but they risk destabilization and collapse, or “spin-offs, split-ups, split-offs,” [62,63] and other forms of splintering into smaller systems, markets, or trade associations if they do not implement affordances for recourse where standards are not met and affordances for formal sanctions where ostracization is no longer practicable or effective.



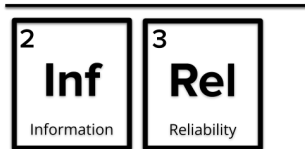
In 11th Century Spain for example, it is at this stage of market maturity we see the introduction of rapidly evolving, voluntary formal constraints on trade, such as third party verification of standards and cooperation with local guilds and magistrates, in response to merchants (especially those alien to the local market) taking advantage of expectations about standards “to the detriment of the customer” [64]. In another example, we can look to the Norden region (Scandinavia and Iceland) in the 9th and 10th Centuries. While this region in this time frame is mostly associated with the famed “Viking Age”, the period of 930 to 1262 is also known as the “Commonwealth Period” in Icelandic history, which is characterized by changes to their governance system and economy. During this period, Norden was home to the development of highly regulated cloth production, checked by dealers, sellers, and regulators in order to maintain quality standards and ensure the use of cut cloth as reference currency in transactions - resulting in a level of reliability that allowed the standard to be used by, and even replicated in, other markets [42].

In addition to providing alternatives to ostracization in the absence of traditional identity fusion, formal standards and the clear claims and records they result in (e.g. was this norm broken?) also act as an information compression feature to restore reputation management capabilities at larger scales and

across distances that would hitherto been highly inefficient or simply not possible [26]. For example, illustrating the effects of this compression across remote multilateral networks, within the 11th Century Jewish Maghribi trading association operating within the Mediterranean, this information compression through formal structure allowed for the remote management of capital, high-throughput information sharing, and the management of insurance policies [65,66]. In numerous other examples, trade and merchant guilds established standards, and did so through a form of local monopoly. While monopolies often carry negative associations, in the earlier stages of market development these monopolies managed by trade associations could be argued to serve a vital role in developing the necessary reliability and organizational coherence for self-regulation processes, such as problem identification and implementation of solutions [67]. Further, analyses on the history of market design have suggested that “guild monopoly rights in [their] home locality may have been instrumental in advancing trade with other localities” [3].

Far and away, the “Champagne fairs” are the most impressive in terms of developing complex methods for improving reliability and recourse. For example, “a merchant could not enter the fair without being in good standing”, and any merchants caught breaking rules of conduct were not allowed to leave until damaged parties were made whole through the fair’s courts [44]. In addition to these stringent controls on input and output, there was a clarity of rules and formal procedure which allowed governing bodies outside the fair to cooperate in extradition, arrest, and the management of other penalties where individuals had left the fair but reneged on contracts and credit agreements or had failed to meet payment arrangements [46]. Traditionally, law is primarily seen as exclusively within the purview of the state, however, the “spontaneous evolution” of and the voluntarily compliance with the fairs’ codes and regulations, or “soft law” [68] appears to have developed to a far more advanced state than that of the governing bodies of the time [43] - so much so, that while other governing bodies recognized the fairs’ judgment, the fairs did not necessarily recognize those of other

governing bodies [46]. They managed to succeed in maintaining voluntary compliance through a “bundling of the services which are valuable to the individual trader with services that are valuable to the community, so that a trader pursuing his individual interest serves the community’s interest as well” [44].



More important than input and output controls on participants, was the input and output standards and controls placed on contracts and their resolution [44,46] - which effectively formalized property rights, an inescapable requirement for the market to mature past an adolescent state [3,45]. Further, the formalization, establishment, and enforcement of protocols related to property rights constituted the development of *lex mercatoria*, or the “law merchant” (i.e. mercantile law), which still stands as the underlying foundation for interjurisdictional (e.g. international) trade [43]. While the development of *lex mercatoria* certainly stands as a monument to human achievement in terms of commercial law and markets, it also serves as an excellent example of the generalization of evolutionary principles to mechanism and protocol regarding shared standards, controls, recourse, and trust signals. The general, flexible structure of underlying protocols allowed for their rapid spread to other markets [44], and allowed for use-case specific adaptation both independently and in parallel to the state in such a way that its fundamental structure is still present in commercial law today [68,69].

Specialization



In addition to reliable and use-case flexible protocols encouraging interjurisdictional trade, they also offer the underlying foundation for specialization of agents and institutions within the market [69]. Reliable institutions “encourage production by fostering saving, investment in human and physical capital, and development and adoption of useful knowledge” [69]. To continue with the use of the example of European trade fairs and other groups of the time, such as the Maghribi and Genoese [70]: this element is instrumental in the “medieval commercial revolution” built on *lex mercatoria* and its

cousins. This revolution saw the “invention, diffusion, or earliest perfection of holding companies, of cashless transactions using bills of exchange, of contracts for marine insurance, and of advanced bookkeeping techniques including... double-entry accounting”, allowing for collective de-risking of remote, long-distance, and interjurisdictional trade practices in a way that had never been possible before [45]. These specializations, such as insurance, accounting, and securities generation, went on to constitute their own markets entirely, serving as a nexus between markets, spreading reliability and risk mitigation as a definable benefit to bring to market in and of itself [71].



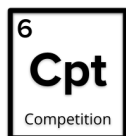
A market reaching this level of maturity generates a hitherto unseen level of pressure on information flows, due to interaction volumes reaching a point that they can be used to generate new knowledge or benefits via aggregation of *data*. It is at this level of maturity that markets begin to express the level of sophistication we might see in the markets of present day - for example, in the rice-futures market of Tokugawa-era Japan [72,73]. As a result, markets for information *about* markets can now form, creating the strange-loops and self-referential patterns which can imbue a system with “unexpected richness” [74]. This unexpected richness can be expressed in the rapid growth in intermediaries in exchange enabled by sophisticated data and information flows, which can increase the value of assets, reduce risks, and improve liquidity (A. Bernstein, Hughson, and Weidenmier 2019), or in the simple provision of information which helps intermediaries and other participants calculate risk, further improving liquidity and enabling advanced derivatives [71]. In markets with the necessary distributed capabilities, we can also see the development of information markets about information markets, such as prediction markets and similar systems [75].

A formalization of the benefit of this reliability, in terms of specialization, can potentially be found in the relationship between reliability and the potential depth and complexity of specialization. For the purposes of this discussion:

- Complexity refers specifically to the number of a specialization's complementary and supplementary connections with, and dependencies on other specializations within a market. For example, a shepherd focused on sheep might be considered to have limited complexity, whereas a blacksmith focusing on armor components might be considered to have relatively high complexity in terms of their specializations' respective positions in the market.
- Depth refers specifically to a specialization's place in a hierarchical order of dependencies which result in the objects or benefits for which the market might be most closely associated. For example, a shepherd focused on sheep might be considered to have a specialization of low depth, given their relative position in a market focused on the production of wool, whereas a miner focusing on iron might be considered to have a relatively high depth in a market focused on the production of armor.

Axiomatically, the more a market's reliability grows, the less risk is associated with investment in specialization depth and complexity. This reduction in risk axiomatically increases the system's tendency toward investment in its components - explaining some of the expressions of this element detailed above. In terms of biological markets, this element is expressed in the evolutionary game theory of niche development, where the long-term stability of the environment facilitates high levels of local specialization [76,77].

Competition



At the level of individuals, this investment in depth of specialization provides a much needed function for a system growing not just in terms of interaction volume, but also in number of actors: reducing the impact of crowding and offering new opportunities to newcomers for competitive advantage where incumbent actors have significant advantages.

However, the potential for depth is not infinite and, as suggested above, it is inextricably connected to the level of maturity of the market. Past work on market design suggests that where a market fails to facilitate a depth and complexity proportionate to the number and relative influence of its incumbent agents, and has no the formal constraints to foster competition, it will begin to rapidly degrade in terms of its quality as a mechanism which takes self-interest as an input and outputs collective utility [3]. Given that complex economic systems, in general, have tendency toward expressing power law distributions, and that the incentives for gaining outsized control over interactions in a reliable, high volume market are very high - the ability to embed systemic checks on outsized influence by actors or clusters of actors within a market becomes more and more essential as it matures. These systemic checks, as opposed to simple penalties, are necessary as the incentives may grow to an extent that, despite the potential for sanctions, the game theory begins to favor risky actions such as attempting to gain illicit advantages in recourse affordances (bribes), developing secret coalitions (conspiracy and collusion), and other difficult-to-discover rule-breaking behaviors. Further, incumbent participants developing outsized influence or control over the market does not necessarily require collusion, bad-faith, or even intentionality, as all of the following factors can contribute to barriers to entry which constitute the de facto establishment of monopoly:

- Advanced production techniques by established firms, which are inaccessible to new entities, that offer either cost or quality advantages which are consequently inaccessible
- "Imperfections in the markets" for services, credit, materials, or other benefits and resources, or "ownership or control by agreement" of these strategic factors by incumbent entities
- "Accumulative preference of buyers" for established incumbents

- Economy of scale or other efficiency advantages offered to large incumbents which are unattainable by newcomers

[78]\

Resilience



Whether outsized influence is checked or not, markets at high levels of maturity seem to be tied to another element, which could be referred to as resilience - or, alternatively, a risk motif, which might be referred to as fragility, in the case that resilience fails to be established. Mature systems of all kinds have a tendency to suffer from their own successes in optimization and reliability.

As a system's components...

- become more specialized and optimized for certain tasks, they become less capable of adaptation to changes in the environment
- build on the reliability of other components, they become more dependent on their continued operation and less tolerant to disruption and fault
- contribute to the system's overall complexity through meaningful interconnection with and dependency on other components, new complex threat surfaces emerge [36] and, consequently, the potential for network impacts of faults from individual components and the risk of cascading failure increases

The interconnection between these 3 factors expresses itself, as noted, in a tendency toward either fragility or resiliency. Resiliency in biological systems is often achieved through numerous layers of "safety nets", with a key example being the adaptation of photosynthesis toward high levels of redundancy rather than efficiency [79]. In human social systems (societies), where the apparent natural tendency is toward developing hierarchical centralization, there are numerous historical examples of rapidly increasing social and economic complexity

followed by rapid and catastrophic collapse [80]. In one example, which illustrates the notion of social systems as-social-markets (as might be found in ethological [52] and social market analyses [53]), and the generalization of the elements listed here to systems which may not traditionally be defined as markets, we can consider the following account related to the c. 2000 B.C. Harappan Civilization of northwestern India:

"[The Harappan Civilization had] gridded, standardized streets, [seaports, massive granaries], and systems of drainage and refuse disposal... [and] a striking uniformity through time and space in pottery, ornaments, bricks, weapons, implements of bronze and stone, seals, and civic planning... Yet by roughly 1750 B.C. this regional uniformity... had broken down... Street frontages declined, brickwork was less careful, bricks from older buildings were reused in new expedient ones, older buildings were subdivided... expressive art became simpler... groups of unburied corpses were left lying in the streets... [and] Harappan occupation was followed by people who lived among the ruins in flimsy huts"

[80]

This account is remarkably similar to accounts of the Roman Colosseum in the time after the collapse of the Roman Empire, during which time the historical monument was used by squatters, dismantled in pieces for external construction projects and makeshift "shacks... nestled in and around the building", used as a place to dispose of or bury bodies, and even used as stables for grazing animals [81]. Other examples of the more general pattern of increasing complexity followed by collapse include the Bronze Age Collapse [82] and the collapse of the Hittite, Minoan, Western Chou, and Mycenaean civilizations [80].

In terms of commercial markets specifically, we see this pattern emerge in enough instances to warrant its own category of literature on specific underlying sub-patterns which lead to

collapse, such as information feedback loops and poor cognitive security of participants (manias), interaction volume spikes (e.g. from panics), and complex interconnection [83]. Of course, among the most famous of the examples in terms of collapses in markets as they would be traditionally defined, is the cascading collapse in US capital markets in 2008 - which was the result of complex interconnection between bundles of mortgage derivative products. Often, the only solution in these kinds of situations is to slow things down, to allow good information to catch up to bad (especially in the case of panic) [83] or to pad the system with extra resources in order to manipulate risk analysis and adjust perceptions of the market.

As opposed to collapse at the level of societies, markets have the opportunity for restoration where there are stakeholders that find it worthwhile to invest in restoring functionality. For example, in the case of the East India Company of the 18th Century: following a series of incidents in Bengal the Company was left with an excessive amount of debt and unpaid tax. The interdependence of many of the European banks with and on the company meant that, “when knowledge of this became public, 30 banks collapsed like dominoes across Europe, bringing trade to a standstill” [84,85]. However, being seen as being “too big to fail” they were given a relatively large bailout and allowed to continue operations [85].

Sustainability



It would appear that the global, interconnected markets of today are testing the limits of their resiliency through the disruptions caused by the COVID-19 pandemic and, at the time of writing, the recent breakout of the second Russo-Ukrainian War, as well as through the impact of related sanctions and potential for spill-over conflicts. The emergence of these kinds of risks facilitates a focus on pragmatics in terms of prioritization of concerns - given that ensuring the continued supply of food and fuel during crisis is of paramount importance. However, as these kinds of risks subside, and markets of high levels of maturity are left to operate in relative peace, a new element comes into focus

- progress toward sustainability and the reduction of externalities. Even if a market is able to:

- manage information flows proportionate to its needs,
- maintain reliability in exchange outcomes,
- provide recourse affordances where exchange outcomes are substandard,
- maintain enough reliability to encourage depth of specialization,
- foster competition, and
- maintain resilience in the face of endogenous or exogenous disruptions to operations

it will run into new existential risks if it cannot meaningfully address the negative externalities it generates for the systems around it [3]. For example, collapses in capital markets are often followed by new regulations which threaten the sovereignty of the market [83].

While the need to address sustainability would appear at first glance to be something that only comes with high levels of market maturity, it seems that sustainability appears as an important element at lower levels of maturity where the market is concerned with public goods, or goods which are shared between collections of actors. The resource or environment in which the resource is contained is generally referred to as a *commons*:

“In a commons, the resource can be small and serve a tiny group (the family refrigerator), it can be community-level (sidewalks, playgrounds, libraries, and so on), or it can extend to international and global levels (deep seas, the atmosphere, the internet, and scientific knowledge). The commons can be well bounded (a community park or library); transboundary (the Danube River, migrating wildlife, the Internet; or without clear boundaries (knowledge, the ozone layer)”

[86]

Commons, both in terms of common resources and in terms of common rights, existed long before their definition, seemingly as the default “prior to written records” [87]. Among the earliest defined commons in history, is that which is defined in the Brehon, or *breitheamh* (meaning judge), laws of Ireland. Though they were first recorded in writing in the seventh century [88], the roots of the tribal Brehon legal system are suggested to be prehistoric [87], being passed on orally for centuries in traditional “poetic utterance” [89]. Accounts of its use continue into the 17th Century, where it was drawn on to divvy up tillage rights to common land on an annual basis based on the quality of the soil and other factors [90,91].

A full exploration of the notion of a commons is beyond the scope of this work - however, it is worth noting that both purely centralized management and privatization of common property “are both associated with more degradation than resulted from a traditional group-property regime”, and that the following appear to be stable principles which emerge from analysis of successfully managed, sustainable commons:

- “Clearly defined boundaries
- Rules that are well matched to local needs and conditions
- Individuals affected by these rules can participate in their modification
- The right of community members to devise their own rules is respected by external authorities
- A system for self-monitoring members’ behavior has been established
- A graduated system of sanctions is present
- Community members have access to low-cost conflict-resolution mechanisms
- Nested enterprises - the appropriation, provision, monitoring and sanctioning, conflict resolution, and other governance activities are organized in a nested structure with multiple layers of activities.”

Discussion

In this paper, elements related to the maturity of function of a market were explored with the use of an operational definition of markets developed using fuzzy set theory. The driving questions of this exploration were:

- At what stages do markets, as mechanisms, begin to degrade in terms of producing collective utility through decentralized coordination?
- What is the relationship between interaction volume and challenges to market operations?
- To what extent can market mechanisms be used to solve problems in the information environment?

What was found is that the mechanisms markets used to solve challenges of reliability and liquidity, whether they were in biological, social, or traditional markets, were generally addressing problems in the information environment as a means of addressing those higher order problems. Further, that markets in early stages of development act as a mechanism, not just for decentralized coordination of production and allocation [2], but also for the development of information exchange systems. For example, problems with reliability required semiotics (common symbolic design and reference) and measurement solutions, and problems of dishonest behavior required reputation management systems. Even in the case of reducing the impact of crashes, solutions often come in the form of psychological adjustment as either first order (market slow downs to give participants more time to consider decisions) or second order (adding resources to a system to adjust risk analysis of participants) effects of policy. This is to say that the influence of supply and demand are limited in their influence by information affordances and capabilities of the participants - as one could say of a tree falling in a forest with no one around to hear, if there is no information available about availability of supply, does it drive prices?

While more work is certainly necessary to further investigate and formalize the detailed elements and the stages of maturity in markets over time, the development of these elements of emergence, information, reliability, recourse, specialization, competition, resilience, and sustainability do appear to be useful in understanding the level of market maturity and the emergence of related challenges, solutions, and adaptations. However, of more importance is the relationship they reveal between information and the maturity of the market. The primary intent of this exploration was to understand the elements related to maturity in market mechanisms and how they relate to solving problems of trust and authenticity in exchange (e.g. liquidity, standards, and recourse), in the interest of seeing

how market mechanisms might be applied to solving problems in the information environment. At any level of maturity, markets are revealed to be universally accompanied by information processing, sharing, and management components facilitated by (or in the form of) controls and standards as a means of enabling continued operations and further development. While these mechanisms of controls and standards settings are of obvious value to the modern information environment, more exploration is needed to consider the practical aspects of applying them and, given their natural emergence in past markets, to consider why appropriate controls have not yet appeared at scale in the information environment [26]. Perhaps most important, and in need of more specific investigation, is the evolving role of trust within these information components.

Funding and Acknowledgements

R.J. Cordes is funded through the NSF Convergence Accelerator Trust and Authenticity in Communication Systems Program (NSF 21-572), under award ID #49100421C0036 and is supported in research efforts through a Nonresident Fellowship with the Atlantic Council on appointment to the GeoTech Center.

Thank you to Sam Young for key contributions to the discussion of fuzzy set theory.

Thank you to Daniel A. Friedman for providing key citations and helping to refine the discussion of biological markets and eusocial communication.

Thank you to Scott David for the numerous clarifications regarding commercial law prior to writing.

Works Cited

1. University of Washington IRSIRI. NSF Convergence Accelerator: Verified Information Exchange Environments Call for Submissions. 2021 Nov.
2. Milgrom PR, Roberts J. Economics, Organization, and Management. Prentice-Hall; 1992.
3. McMillan J. Reinventing the Bazaar: A Natural History of Markets. W. W. Norton & Company; 2003.
4. Karachiwalla R, Pinkow F. Understanding crowdsourcing projects: A review on the key design elements of a crowdsourcing initiative. *Creat Innov Manag*. 2021;30: 563–584.
5. Rosenbaum EF. What is a Market? On the Methodology of a Contested Concept. *Rev Soc Econ*. 2000;58: 455–482.
6. Simmel G. The philosophy of money. Routledge; 2004.
7. Nietzsche FW, Hollingdale RJ. On the Genealogy of Morals. Vintage Books; 1989.
8. Kaplan HS, Schniter E, Smith VL, Wilson BJ. Risk and the evolution of human exchange. *Proc Biol Sci*. 2012;279: 2930–2935.
9. Hill KR, Walker RS, Bozicević M, Eder J, Headland T, Hewlett B, et al. Co-residence patterns in hunter-gatherer societies show unique human social structure. *Science*. 2011;331: 1286–1289.
10. Isaac G. The food-sharing behavior of protohuman hominids. *Sci Am*. 1978;238: 90–108.
11. Orlan A. The Empire of Value: A New Foundation for Economics. MIT Press; 2014.
12. Cibulski L, Wascher CAF, Weiss BM, Kotrschal K. Familiarity with the experimenter influences the performance of Common ravens (*Corvus corax*) and Carrion crows (*Corvus corone corone*) in cognitive tasks. *Behav Processes*. 2014;103: 129–137.
13. Brosnan SF, De Waal FBM. Monkeys reject unequal pay. *Nature*. 2003;425: 297–299.
14. Hojo MK, Pierce NE, Tsuji K. Lycaenid Caterpillar Secretions Manipulate Attendant Ant Behavior. *Curr Biol*. 2015;25: 2260–2264.
15. Noë R, Hammerstein P. Biological markets. *Trends Ecol Evol*. 1995;10: 336–339.
16. McDonald M. Market Segmentation: How to Do It and How to Profit from It. John Wiley & Sons; 2012.

17. World Bank. World development report 1996 from plan to market: From plan to market. New York, NY: Oxford University Press; 1996.
18. Ioannides YM. Evolution of Trading Structures. In: Arthur WB, Durlauf SN, Lane DA, editors. The Economy as an Evolving Complex System II. Santa Fe Institute; 1996.
19. Zadeh LA. Fuzzy sets. Information and Control. 1965;8: 338–353.
20. Zimmermann H-J. Fuzzy set theory. Wiley Interdiscip Rev Comput Stat. 2010;2: 317–332.
21. Maiers J, Sherif YS. Applications of fuzzy set theory. IEEE Trans Syst Man Cybern. 1985;SMC-15: 175–189.
22. Ragin CC. Fuzzy-Set Social Science. University of Chicago Press; 2000.
23. Ankei Y. Fish as “Primitive Money”: Barter Markets of the Songola. Senri Ethnol Stud. 1984. Available: https://minpaku.repo.nii.ac.jp/?action=repository_action_common_download&item_id=3324&item_no=1&attribute_id=18&file_no=1
24. Haklai M. Visualising Roman Institutional Environments for Exchange as a Complex System. In: Verboven K, editor. Complexity Economics: Building a New Approach to Ancient Economic History. Cham: Springer International Publishing; 2021. pp. 125–159.
25. David S, Cordes RJ, Friedman DA. Active Inference in Modeling Conflict. 2021. doi:10.5281/zenodo.5759807
26. Cordes RJ, Applegate-Swanson S, Friedman DA, Knight VB, Mikhailova A. Narrative Information Management. Zenodo. COGSEC; 2021. doi:10.5281/zenodo.5573287
27. Way MJ. Mutualism Between Ants and Honeydew-Producing Homoptera. Annu Rev Entomol. 1963;8: 307–344.
28. Fullbrook E. Pluralist Economics. Bloomsbury Academic; 2008.
29. Verboven K, editor. Complexity Economics: Building a New Approach to Ancient Economic History. Springer Nature; 2020.
30. Lee F. Heterodox Economics. The Long Term View. 2008;7.
31. Colander D, Föllmer H, Haas A, Goldberg MD, Juselius K, Kirman A, et al. The Financial Crisis and the Systemic Failure of Academic Economics. Kiel Institute for the World Economy; 2009. doi:10.2139/ssrn.1355882
32. Colander D. Pluralism and Heterodox Economics: Suggestions for an “Inside the Mainstream” Heterodoxy. Middlebury College, Department of Economics; 2007 Oct. Report No.: 0724. Available: <https://ideas.repec.org/p/mdl/mdlpap/0724.html>

33. Savageau MA. Growth of complex systems can be related to the properties of their underlying determinants. *Proc Natl Acad Sci U S A*. 1979;76: 5413–5417.
34. Gordon DM. The ecology of collective behavior. *PLoS Biol*. 2014;12: e1001805.
35. Gell-Mann M. *The Quark and the Jaguar: Adventures in the Simple and the Complex*. Macmillan; 1995.
36. Cordes RJ, Friedman DA. Emergent Teams for Complex Threats. *The Great Preset: Remote Teams and Operational Art*. COGSEC; 2020.
37. Gell-Mann M. Plectics: The study of simplicity and complexity. *Europhys News*. 2009;33: 17–20.
38. Page SE. A complexity perspective on institutional design. *Politics, Philosophy & Economics*. 2012;11: 5–25.
39. Arthur WB, Durlauf SN, Lane DA, editors. *The Economy as an Evolving Complex System II*. Santa Fe Institute; 1996.
40. Lankenau SE. Smoke'em if you got'em: Cigarette black markets in US prisons and jails. *Prison J*. 2001;81: 142–161.
41. Hammerstein P. *Genetic and Cultural Evolution of Cooperation*. MIT Press; 2003.
42. Smith MH. 3. Weaving Wealth: Cloth and Trade in Viking Age and Medieval Iceland. *Textiles and the Medieval Economy: Production, Trade and Consumption of Textiles, 8th-16th Centuries*. 2014; 23–40.
43. Benson BL. The Spontaneous Evolution of Commercial Law. *South Econ J*. 1989;55: 644–661.
44. Milgrom PR, North DC, Weingast* BR. The role of institutions in the revival of trade: The law merchant, private judges, and the champagne fairs. *Econ Polit*. 1990;2: 1–23.
45. Reinert S, Fredona R. Merchants and the Origins of Capitalism. Business School BGIE Unit Working Paper. 2017. doi:10.2139/ssrn.3037173
46. Sgard J. Global economic governance during the middle ages: The jurisdiction of the champagne fairs. *Int Rev Law Econ*. 2015;42: 174–184.
47. Reinecke JE. Trade Jargons and Creole Dialects as Marginal Languages. *Soc Forces*. 1938;17: 107–118.
48. Hancock IF. *Readings in Creole Studies*. John Benjamins Publishing; 1979.
49. Vyatkin A, Metelkin I, Mikhailova A, Cordes RJ, Friedman DA. Active Inference and

- Behavior Engineering for Teams. In: Friedman DA, Cordes RJ, editors. *The Great Preset: Remote Teams and Operational Art*. COGSEC; 2020.
50. Virant-Doberlet M, Kuhelj A, Polajnar J, Šturm R. Predator-Prey Interactions and Eavesdropping in Vibrational Communication Networks. *Frontiers in Ecology and Evolution*. 2019;7. doi:10.3389/fevo.2019.00203
 51. Virant-Doberlet M, Mazzoni V, de Groot M, Polajnar J, Lucchi A, Symondson WOC, et al. Vibrational Communication Networks: Eavesdropping and Biotic Noise. In: Cocroft RB, Gogala M, Hill PSM, Wessel A, editors. *Studying Vibrational Communication*. Berlin, Heidelberg: Springer Berlin Heidelberg; 2014. pp. 93–123.
 52. Johnson C. Exploring social markets, partner debt, and mimetic currency in dolphins. *Anim Behav Cogn*. 2016;3: 224–242.
 53. Dietler M. Driven by drink: The role of drinking in the political economy and the case of Early Iron Age France. *Journal of Anthropological Archaeology*. 1990;9: 352–406.
 54. Dunbar RIM. *Grooming, Gossip, and the Evolution of Language*. Harvard University Press; 1998.
 55. Lang M, Xygalatas D, Kavanagh CM, Boccardi N, Halberstadt J, Jackson C, et al. Outgroup threat and the emergence of cohesive groups: A cross-cultural examination. *Group Process Intergroup Relat*. 2021; 136843022110169.
 56. McPherson M, Smith-Lovin L, Cook JM. Birds of a Feather: Homophily in Social Networks. *Annu Rev Sociol*. 2001;27: 415–444.
 57. Forgas JP, Haselton MG, von Hippel W. *Evolution and the Social Mind: Evolutionary Psychology and Social Cognition*. Psychology Press; 2011.
 58. Williams KD, Forgas JP, von Hippel W, editors. *The social outcast: Ostracism, social exclusion, rejection, and bullying*. Sydney Symposium of Social Psychology series. 2005;366. Available: <https://psycnet.apa.org/fulltext/2005-13813-000.pdf>
 59. Whitehouse H, François P, Savage PE, Currie TE, Feeney KC, Cioni E, et al. Complex societies precede moralizing gods throughout world history. *Nature*. 2019;568: 226–229.
 60. Whitehouse H, François P, Savage PE, Currie TE, Feeney KC, Cioni E, et al. Retraction Note: Complex societies precede moralizing gods throughout world history. *Nature*. 2021;595: 320.
 61. Haidt J. *The Righteous Mind: Why Good People Are Divided by Politics and Religion*. Knopf Doubleday Publishing Group; 2012.

62. Holzman RS. SPIN-OFFS, SPLIT-UPS, AND SPLIT-OFFS. *Natl Tax J.* 1952;5: 277–278.
63. Mintz SS. Divisive Corporate Reorganizations: Split-Ups and Split-Offs. *Tax L Rev.* 1950. Available:
https://heinonline.org/hol-cgi-bin/get_pdf.cgi?handle=hein.journals/taxlr6§ion=31
64. Escartín González E, Velasco Morente F, González Abril L. On Sevillian guilds towards the end of the 11th century. *Revista crítica de historia de las relaciones laborales y de la política social*, 7. 2013. Available: <https://idus.us.es/handle/11441/76311>
65. Greif A. Contract Enforceability and Economic Institutions in Early Trade: The Maghribi Traders' Coalition. *Am Econ Rev.* 1993;83: 525–548.
66. Greif A. Reputation and Coalitions in Medieval Trade: Evidence on the Maghribi Traders. *J Econ Hist.* 1989;49: 857–882.
67. Porter T, Ronit K. Self-Regulation as Policy Process: The Multiple and Criss-Crossing Stages of Private Rule-Making. *Policy Sci.* 2006;39: 41–72.
68. Kirton JJ, Trebilcock MJ. Hard choices, soft law: Voluntary standards in global trade, environment and social governance. Routledge; 2017.
69. Greif A. Institutions and the Path to the Modern Economy: Lessons from Medieval Trade. Cambridge University Press; 2006.
70. Greif A. The Maghribi traders: a reappraisal? *Econ Hist Rev.* 2012;65: 445–469.
71. Bernstein PL. Against the Gods: The Remarkable Story of Risk. John Wiley & Sons; 2012.
72. Wakita S. Efficiency of the Dojima rice futures market in Tokugawa-period Japan. *Journal of Banking & Finance.* 2001;25: 535–554.
73. Hamori S, Hamori N, Anderson DA. An empirical analysis of the efficiency of the Osaka rice market during japan's Tokugawa era. *J Futures Mark.* 2001;21: 861–874.
74. Hofstadter D. Godel, Escher, Bach: An eternal golden braid. Basic Books; 1979.
75. Bray D, Croxson K, Dutton W. Information markets: Feasibility and performance. University of Oxford; 2008. Available:
https://www.oii.ox.ac.uk/archive/downloads/research/dpsn/Informationmarkets_full.pdf
76. Dawkins R. The Selfish Gene. Oxford University Press; 2016.
77. Kylafis G, Loreau M. Ecological and evolutionary consequences of niche construction for its agent. *Ecol Lett.* 2008;11: 1072–1081.

78. Bain JS. Conditions of Entry and the Emergence of Monopoly. In: Chamberlin EH, editor. Monopoly and Competition and their Regulation: Papers and Proceedings of a Conference held by the International Economic Association. London: Palgrave Macmillan UK; 1954. pp. 215–241.
79. Demmig-Adams B, Cohu CM, Adams WW III. Dealing with the hazards of harnessing sunlight. *Nature Education*. 2012;4: 18.
80. Tainter J. *The Collapse of Complex Societies*. Cambridge University Press; 1988.
81. Hopkins K, Beard M, Beard R in C. *The Colosseum*. Harvard University Press; 2005.
82. Knapp AB, Manning SW. Crisis in Context: The End of the Late Bronze Age in the Eastern Mediterranean. *Am J Archaeol*. 2016;120: 99–149.
83. Kindleberger CP, Aliber RZ, Solow R. *Manias, Panics and Crashes*. Wiley; 2005.
84. Dalrymple W. The East India Company: the original corporate raiders. *Guardian*. 2015;4.
85. Clegg S. The East India Company: The First Modern Multinational? *Multinational Corporations and Organization Theory: Post Millennium Perspectives*. Emerald Publishing Limited; 2017. pp. 43–67.
86. Hess C, Ostrom E. *Understanding Knowledge as a Commons: From Theory to Practice*. MIT Press; 2011.
87. Wall D. *The Commons in History: Culture, Conflict, and Ecology*. MIT Press; 2014.
88. Ranelagh J. *A Short History of Ireland*. Cambridge University Press; 2012.
89. Simms K. THE POETIC BREHON LAWYERS OF EARLY SIXTEENTH-CENTURY IRELAND. *Ériu*. 2007;57: 121–132.
90. Hore HF. Irish Brehons and Their Laws. *Ulster Journal of Archaeology*. 1857;5: 36–52.
91. Westropp HM. On the Tribal System and Land-Tenure in Ireland, under the Brehon Laws. *The Journal of the Ethnological Society of London (1869-1870)*. 1870;2: 342–351.