

Superconnected, Complex and Ultrafast: Governance of Hyperfunctionality in Financial Markets

Authors: Victor Galaz^a, Jon Pierre^b

^a *Corresponding author: Stockholm Resilience Centre, Stockholm University, Sweden*

Email: victor.galaz@su.se

and

Global Economic Dynamics and the Biosphere Programme, Royal Swedish Academy of Sciences, Sweden

^b *Department of Political Science, Göteborg University, Sweden*

and

Melbourne School of Government, University of Melbourne, Australia

Email: jon.pierre@gu.se

Increased trading with financial instruments, new actors and novel technologies are changing the nature of financial markets making trade faster, more information dense and more globalized than ever. These changes in financial markets are not incremental and linear, but transformative with the emergence of a new “machine-ecology” with intricate system behavior and new forms of systemic financial risks. We argue that the nature of these changes pose fundamentally new challenges to governance as they require policy-makers to respond to system properties characterized by not only complex causality, but also extreme connectivity (i.e. global), ultra-speed (i.e. micro-seconds) and “hyperfunctionality”. Governance can fail at the system level if a subsystem performs its function to such an extreme; this could jeopardize the efficiency of the system as a whole. We elaborate in what ways governance scholars can approach these issues, and explore the types of strategies policy-makers around the world use to address these new financial risks. We conclude by pointing out what we perceive as critical research fronts in this domain.

Keywords: complexity; financial markets; algorithmic trade; governance; network governance

1. Introduction

Trade in financial markets relies fundamentally on information flows. Financial trade is in fundamental ways, information. Financial actors such as investors not only make their living by betting on the right stock, bond or futures contract, but also (amongst other strategies) by making quick investment decisions based on the latest financial or political news or shifting expectations amongst other market actors.

The speed of these information flows has become increasingly important. As computing power continues to increase exponentially, and computer algorithms become progressively sophisticated through machine learning, the capacity of financial actors to process growing amounts of information, design complex trading strategies, and conduce extremely rapid trade in bonds, stocks, commodities and foreign exchange markets (sometimes at the scale of microseconds) also surges.



Algorithmic tradeⁱ (henceforth denoted AT) involves several types of automated trading strategies, each with different ways of making profit with minimal human intervention, and at extremely high speeds. AT has four main strengths compared to conventional trade, according to McGowan (2010, p. 3), Gomber, Arndt, Lutat, & Uhle (2011, 21f), and Narang (2013). First, algorithms have the ability to split up large orders, and execute them in such small portions over time so that market impacts (e.g. unwanted price increases) are minimized. Second, they also have the ability to text-mine different sources of information for “weak signals” – such as the movement of interest rates, very small economic fluctuations, sentiments in financial news and in social media such as in the micro-blog service *Twitter* – and rapidly execute trade before anyone else in the market is aware of them. Third, algorithms benefit from identifying and rapidly trade on differences in prices between exchanges and platforms, known as “arbitraging between spreads”. Fourth, algorithms are able to place “flash orders” – that is trade based on access to market information for a matter of milliseconds, which is not yet public.ⁱⁱ

While the profit can be extremely small for each individual trade (pennies of a US Dollar for example), algorithmic trade can be executed millions of times a day, thereby generating large gains in aggregate. For example, the quantitative trading firm *Renaissance Technologies* in the U.S. is famous for its impressive 35 percent average yearly returns since 1990 (Narang, 2013, p. 4). In addition, despite the economic recession, algorithmic trade is seen as one of the most lucrative businesses on Wall Street, and is estimated to generate approximately 15-25 billion US Dollars in revenue yearly (McGowan, 2010, p. 3f). These figures are contested however.

Thus, AT is far from a marginal phenomenon. On the contrary, large market players such as hedge, pension, and mutual funds increasingly execute large trades through algorithmic trading. Early estimates show that algorithmic trading has increased from near zero in the mid-1990s to as much as 70 percent of the trading volume in the United States (Hendershott et al., 2011, p.1), 30 percent in the UK, and between 30-50 percent in the European equities markets (Government Office for Science, 2011). AT also is making fast progression into commodity derivative markets (such as futures contracts for cocoa, oil and wheat) in the U.S., Russia, India and China (Galaz, Gars, Moberg, Nykvist & Repinski, 2015).

A number of scholars and institutions have raised numerous concerns of systemic financial risks emerging from these technologies. These concerns are about large price swings and market instability triggered by unforeseen feedback-loops, malicious or incorrectly programmed algorithms and/or incorrect input data (GOS, 2011, 3ff; Lenglet, 2011, 59f; Chaboud, Chiquoin, Hjalmarsson, & Vega 2014). This element of “surprise” created by complexity can be exemplified with the 2010 “Flashcrash”. In the course of about 30 minutes, U.S. stock market indices, stock-index futures, options, and exchange-traded funds experienced an unexpected sudden price drop of more than 5 percent, followed by a rapid rebound (US Commodity Futures Trading Commission & US Securities & Exchange Commission, 2010). Similar unexpected, and very rapid volatility in prices for oil and gas futures have been observed the last few years (GOS, 2011, p. 36). One of the most extreme examples however, must be the ultrarapid \$121 billion loss (and recover) of the value of the stock market index S&P500 in April 2013. In this case, the acclaimed reason was a hijacked Twitter-account of the major news company Associated Press (AP) sending out false messages of a terror attack in the White House, thereby triggering rapid automated sales on the market. The progression of these technologies hence not only carries with them possible benefits (such as increased liquidity, reduced volatility, or reduced transactions costs), but also wider and highly debated financial risks.ⁱⁱⁱ

1.1. Aims of this paper

In this paper, we argue that AT pose a number of new interesting insights into the governance of complexity, but complexity of a very specific sort: superconnected, ultrafast and hyperfunctional. Here we ask:

1. What new system properties make AT in financial markets interesting from a complexity governance perspective?
2. How can these properties be studied from a governance perspective?
3. What are the most important emerging governance responses deployed by decision-makers and private actors trying to respond to these new properties?

Question 1 is elaborated in detail part 2 below. In part 3 we discuss how these properties pose challenges to existing theoretical approaches. In part 4 we elaborate question 2 by unpacking key governance functions in the context of AT. In part 5, we explore question 3 by investigating emerging generic governance strategies employed by policy-makers in different parts of the world with the intention to harness AT. We conclude this article by pointing out a number of intriguing questions for scholars who are interested in the governance of these sort of ultrafast, superconnected and hyperfunctional systems.

2. Superconnected, Ultrafast and Hyperfunctional

Financial markets are sometimes portrayed as complex adaptive systems – systems whose behavior is in constant flux, prone to quite intricate emergent patterns including unavoidable uncertainties, cascading failures, and surprise (e.g. Sornette, 2009; May, Levin & Sugihara, 2008). Continuous innovation and evolution are key aspects of financial markets as hardware, software and human innovation drive the system towards higher (perceived at least) efficiency, connectivity and speed over time (Chesini & Giaretta, 2014; Galaz, 2014). The speed of innovation in financial markets and associated technologies however, has created new forms of system properties that until now remain to be explored by governance scholars. Three properties are of specific interest in this context: *connectivity*, *speed* and *hyperfunctionality*.

2.1. Connectivity

During the past decade it has become increasingly clear that connectivity in financial markets had amplified over time, almost to the point that these could be denoted as *superconnected*. By “connectivity” we mean that flows of information and financial resources have expanded to cover not only larger geographical areas, but also an increasing number of economic sectors in society. For example, stock exchanges have merged across continents in the last decades, thereby creating information channels that link market places across continents in ways that were unimaginable just a few decades ago. The merger between the New York Stock Exchange and Euronext in 2007 is one case in point (Karmel, 2007). Algorithm based trading platforms nowadays also allow for trade with all sorts of financial instruments (ranging from futures to stocks and commodity derivatives), in any market around the world thereby contributing to additional connectivity.^{iv}

Recent analyses also show that there are increased connections between what historically used to be separated asset classes. Examples include the increased merger between financial

capital and economic sectors involving technological and basic materials (Harmon, Stacey & Bar-Yam, 2010); financial capital and commodity derivatives such as commodity futures (Galaz *et al.*, 2015); and financial capital and natural resources through the emergence of financial instruments such as biodiversity, forests, fisheries and weather bonds (i.e. “catastrophe” bonds, see Business and Biodiversity Offsets Programme & the UNEP Finance Initiative, 2010).

2.2. Speed

Information flows in financial markets are so fast as to over-perform human information processing capacities by several orders of magnitude. And technological innovation continues to push speed limits. In 2011, for example, the firm *Fixnetix* developed a microchip that can help algorithms execute trades in 740 nanoseconds – 740 billionth of a second (0.000000740 seconds).^v In 2013, American news agency CNBC reported on a server farm situated in Washington able to transmit economic data for trading at near light speed to New Jersey, via a superfast microwave transmission service.^{vi} These explosive increases in speed are tightly coupled to information technological advances, creating what some have denoted a technological “arms race” between algorithmic trading actors (Lewis, 2015; Snider, 2011; Chaboud *et al.*, 2014).

This race towards increasingly rapid trades has not only created intriguing phenomena such as extremely rapid volatility in stock prices (denoted “subsecond extreme events”, Johnson, Zhao, Hunsader, Qi, Johnson, Meng & Tivnan, 2013), and the emergence of “predator algorithms” (i.e. algorithms designed to spy on, or crack the codes of other algorithms, see Rose, 2010; Weber, 2011). This change is so drastic that some have proposed that global financial markets have evolved into a new “machine ecology” where changes in the system’s behavior are considerably faster than human response time (Johnson *et al.*, 2013). In short: the speed of information flows in modern financial markets effectively surpasses human capacity to detect and respond to it.

2.3. Hyperfunctionality

Speed and connectivity in combination create what we call “hyperfunctionality” in financial markets. The notion of hyperfunctionality is widespread. In industrial design, hyperfunctionality is used to describe an optimal fitness for purpose or the “disappearing tool”, i.e. tools that are so well adapted to the user’s need that s/he is longer aware that s/he is actually using a tool such as a computer (Kettley, 2012). In a different genre, Baudrillard (2006) uses hyperfunctionality to describe a variety of phenomena, including consumers’ constant search for machines that work faster than the previous computer or smartphone. The most common application of the hyperfunctionality concept is however in medicine, describing pathologies where bodily organs such as for instance the hypothalamus, produce excessive amounts of a particular hormone.

In the present context of financial markets and AT, we use hyperfunctionality in a similar perspective as the latter. We see hyperfunctionality as a systemic pathology caused by an over-performing subsystem in the wider context of economic governance. The root cause of the problem is that while decision making is an essential component of financial management and market behavior, algorithms perform that function infinitely faster than decision makers in any other areas of economic governance (for examples of these areas see Gamble, 2000). Just as a hyperfunctioning hypothalamus causes problems not to the hypothalamus itself but rather to other bodily organs, so too can hyperfunctioning algorithms in highly connected financial

markets cause problems in other areas of economic governance by undermining the trust and stability of financial systems (discussed in the introduction).

3. Theoretical Approaches to Algorithmic Trade

How can governance scholars approach this sort of hyperfunctional, hyperfast and complex system? A number of scholars have explored the challenges posed by the recent transformation of financial markets from a legal perspective (e.g. Gomber & Gsell, 2006; Chesini & Giaretta 2014; MacNamara, 2015). However, few if any, have elaborated how this dramatic change in financial markets challenges more general principles or functions of governance (*sensu* Pierre & Peters, 2005; Koppenjan & Klijn, 2004; Hooghe & Marks, 2003; Bell & Hindmoor, 2009).

A number of theoretical approaches or lenses are possible to apply in this context. Existing theories of economic and financial governance provide important insights. Financial markets, like all markets, have regulatory frameworks defining proper conduct and methods of exchange in that market. These regulatory frameworks can either be imposed by a higher-level authority—typically the state—or be deliberated among the market actors into a self-regulating regime (Lindberg, Campbell & Hollingsworth, 1991). Similar helpful academic discussions can be found in the governance literature exploring market regulation. Regulations articulate the public interest and address collective action problems in markets, but excessive or poorly designed regulation jeopardizes the allocative efficiency of the market (Eisner, 2000; Levi-Faur, 2006). Therefore, regulators typically tread carefully, searching for a “sweet spot” that regulates the market according to political preferences without choking the efficiency of the market. Globalization has however to some degree undermined the strength and effectiveness of domestic regulatory frameworks (Eisner, 2000). An alternative approach to understanding governance dimensions of AT could be theories of network governance. Networks offer opportunities for informal collaboration towards specific collective goals among actors who may be pitted in competition with each other in other respects (Torfing & Sørensen, 2007). The idea that market actors form networks to overcome collective action problems or to generate economies of scale is not new (e.g. Johnson, 1982). In this context, theories of network governance become relevant since financial regulation with trade at super-speed and scale require transnational and highly flexible network collaborations between international, state and non-state actors. To our knowledge, such an analysis has not been assumed yet in this domain.

A last possible avenue to a conceptual understanding of AT would be to bring in the literature on *crisis governance*. Again, space will only allow a very brief and condensed account of a very rich literature. A common theme in this literature of relevance in this context, is the fact that crises tend lead to calls to centralize decision-making and control, and to emphasize the role of leadership to coordinate prompt responses (Boin, 2004; Boin, t’Hart & Stern, 2006; Peters, Pierre & Randma-Liiv, 2011). This literature is relevant since AT has brought about crisis-like situations, however putting crisis decision-making in the hands of actors that normally are not studied as crisis managers.

Two important conclusions come out from this very brief review. One is that several theoretical approaches are useful to understand the governance challenges posed by AT in financial markets. The other general conclusion is that all the theories elaborated briefly above tacitly assume either the possibility for centralized decision-making and control, or some form of exchange, communication and deliberation. This action could emerge either among sovereign agents pursuing a joint regime or between those agents and some higher-level authority (say,

national regulators and private financial market actors). As we explore in more detail below, AT does not fit neatly into any of these assumptions due to its inherent system properties and complex governance setting.

Hence there is a need for governance scholars to elaborate in what ways AT challenges basic functions of governance (see section 4), and the ways policy-makers and private actors try to cope with the intriguing governance challenges posed by superconnected, ultrafast, and hyperfunctional systems (see section 5).

4. Governance Functions and Challenges

In order to better understand the governance problems and responses that are associated with AT (explored in the next section) we need to differentiate between phases of the process of governing and policy-making. The stages model of policy-making dates back to Harold Lasswell's work in the 1950's, but it continues to be a useful way to think about the policy-making process even in these settings (for an overview see Hupe & Hill, 2006). In a governance perspective these stages roughly translate into what Peters and Pierre (2016) refers to as *governance functions*. They include *goal definition*, *resource mobilization*, *decision-making* and *implementation*. We will use these functions to elaborate on how AT challenges conventional governance analysis, and as a framework for the assessment of the impact of AT on economic governance more specifically.

4.1. Goal definition

Defining goals for collective action is customarily seen as the province of government since it is a core democratic function that actors and institutions that can be held to democratic account should exercise, normatively speaking. However, markets are known to have a strong indirect influence on these goals, not least due to the economic growth that the market generates (Hall, 1986; Lindblom, 1977). AT could be seen as making a positive contribution to this function by making financial markets efficient by e.g. improving the price discovery mechanism, accelerating the number of trades, reducing transaction costs and increasing liquidity (e.g. Hendershott, Jones & Menkveld, 2011; Vuorenmaa, 2013). However, it has also been suggested that AT leads to sluggish and volatile trade with more extensive ramifications within the market and beyond (Gerig, 2015; Johnson et al., 2013; Kirilenko, Kyle, Samadi & Tuzun 2014; McGowan, 2010). The speed and hyperfunctionality of AT may thus contribute to financial instabilities not only within the financial sector, but also in other sectors and regions through increased connectivity (see previous section).

One such example of a financial cascade was widely debated in the aftermaths of the 2008-2009 "food crises" (Clapp, 2009), and more recent concerns that AT is contributing to excessive price volatility in commodity financial derivative markets such as those for sugar and cocoa (Galaz et al., 2015). Such developments would greatly complicate goal setting as the nature of the problem would constantly mutate. Effective, specified goal setting requires some degree of continuity in the nature of the problem which the policy seeks to address. The fundamental problem here is that while market developments and forecasts are essential to political goal setting—e.g. expected growth rates are a key variable in assessing the government's financial capabilities over some future time period—AT is likely to increase the uncertainty in such forecasting, and therefore increase the uncertainty in goal setting (see for example discussion on

decision-making challenges posed by cascading crises with multiple uncertainties, Galaz, Moberg, Olsson, Paglia & Parker 2011).

4.2. Resource mobilization

Financial markets are integral to the economic performance of a country. For example, the U.S. subprime mortgage crisis in 2007-2009 was not isolated to the financial sector, but had severe repercussions on economic growth, unemployment rates and fiscal policies in general. The complex interdependency between the state and financial markets has been demonstrated on several occasions. The influence of the market on public policy and government action increased dramatically after the deregulation of financial markets in the 1980s and 1990s (Reinhart & Rogoff, 2008; Strange, 1997, 1998). Even so, interdependency, not dominance of one over the other, remains the general pattern. As an example, private financial institutions often ascribe a fundamental role to governments, even in what could be seen as largely deregulated international financial markets (Mosley, 2003).

What is the contribution of AT to resource mobilization? Here, a time perspective and attention to diffusion is important. By virtue of considerably lower transaction speed, and a superior capacity to exploit trends and developments in the market, AT may generate stronger short-term yields and growth in the market compared to conventional financial management. The key drawback of AT is that it may significantly amplify movements in the market, often beyond human control due to its speed and complex patterns (Johnson et al., 2013). Hence it is possible that AT entails market instability and volatility which may be counter-productive to resource mobilization.

Thus, from a wider economic governance perspective, this means possible yields will benefit the owners of the most sophisticated and successful algorithms whereas the downfall of volatility may impact on the market and society in general as a whole (Lewis, 2015; GOS, 2011; Rose, 2010). This suggests that the contribution of AT in resource mobilization may potentially not only be skewed towards benefitting certain high-technologically potent financial actors (Snider, 2014; Chesini & Giaretta, 2014), but also be uncertain from the perspective of policy-makers.

4.3. Decision-making

As is the case with goal setting, political decision-making is normally seen as reserved for democratic institutions as they are responsive and accountable to the electorate. Financial markets and their actors are however rarely present in political decision-making. Indeed, actors in financial markets emphasize that although the market's development may have political causes or consequences, they do not see themselves as political actors (Mosley, 2003; Pierre, 1999). Thus, in a formal sense decision making is reserved for senior elected officials.

The relationship between decision-makers and financial actors is much more complex than this of course. Markets are known to have strong indirect influence on political goals, not only due to the economic growth that they generate, but also through lobbying efforts (elaborated in the next section). Market actors in general prefer to reduce perceived market dysfunctionality through self-regulation rather than through government regulation since it would minimize government intrusion (for a critical account see Pirrong, 1995). At the same time however, financial market leaders are sensitive to even subtle signals from government suggesting, for instance, a regulatory review of the financial system. This phenomenon is of course, not unique

for financial markets (examples from the literature include Johnson's [1982] notion of the "iron fist in a velvet glove" and Scharpf, 1997 on the "shadow of hierarchy". See also Pierre, 1999 for an example from Swedish financial policy after the severe banking crises in the 1990's).

As we will explore more in detail below, the arenas and pathways for democratic decision-making about hyper-fast financial markets are fragmented and opaque and hence they lack a clear leverage for institutional change that would support more transparent decision-making processes.

4.4. Implementation

Deregulation in the 1980s and 1990s *de facto* dis-embedded the market from its national context albeit without reducing its significance in the domestic economy. The ramifications of this disjuncture became obvious during the series of financial crises in the 1990s and early 2000s, particularly the 2007-8 financial crisis in the United States. Since then, governments in most western countries have increased regulation of financial markets. Financial actors have not been passive bystanders in that process however (see Pierre, 2013; see also Bó, 2006 on "regulatory capture"). Thus, financial markets are to some extent both the targets and the agents of the implementation of regulatory reform.

4.5. Feedback, evaluation and learning

Financial markets may indirectly provide important feedback on governance and public policy albeit of a rather biased sort. Governance actions or policy programs which are seen as hostile to the financial market for example, may result in declining flows of capital and a reallocation of investment capital. Such action, whether actual or anticipated, can exert tremendous influence on policy choices (Pierre, 1999). This type of feedback is not uncontroversial; although the market is sometimes said to have a "privileged position" in domestic policy making (Lindblom, 1977), other social constituencies may well argue that government and public policy must take a broader view and not cater unilaterally to the interests of financial markets. This simple dichotomy between financial interests versus the public interest and is however blurred by the fact that clients with stakes in financial markets, are also voters and hence represent a powerful political constituency.

Speed is also an issue in this regard. The temporal scales at which AT operates are so fast, as to over-perform human information processing capacities by several orders of magnitude. As we will explore more below, this poses decision-makers with difficult challenges as they attempt to make sense of rapidly changing circumstances, evaluate ongoing financial activities and learn from surprise or mistakes.

Let us now turn to the flipside of that discussion and see how political actors and institutions are trying to seek to gain control over AT despite these severe challenges to well-known governance functions. This exploration works as a means to explore emerging governance strategies deployed to harness these highly complex and fast systems.

5. Governing the Algorithm – Current Governance Responses

The emergence of AT hence creates difficult challenges for decision-makers as they try to set goals, mobilize resources, identify clear decision-making pathways, implement decisions, and

continuously learn from changing circumstances. However, political decision-makers are far from powerless. They can produce governance responses that differ from steering functions normally explored by governance scholars since they focus on getting a grip of phenomena characterized by complexity, speed and the potential for propagating failure. In addition, private actors such as stock exchanges have strong (economic) incentives to contribute to improved oversight to maintain public trust in the inner workings of the financial system.^{vii}

Below we explore these governance responses summarized under the headings increasing transparency, slowing down, and decoupling. These are intended to capture an important set of currently unfolding governance activities assumed by state (such as government agencies) and non-state actors (such as stock exchanges). As Fleckner (2015) notes however, regulation in this domain takes place through a “bouquet of rules, norms and standards (p. 15). The presentation below should therefore be seen as a selection of important and illustrative governance responses in the context of ultrafast and complex systems worth further exploration.^{viii}

5.1. Increasing Transparency

It is well known that the effective governance of complexity requires adaptive learning and flexible responses to changing circumstances (Pierre & Peters, 2005; Folke, Hahn, Olsson & Norberg 2005; Weick & Sutcliffe, 2007; see also previous section on feedback, evaluation, and learning). This, however, requires continuous flows of correct information and changes in key parameters as a means to support sense making processes, mechanism for overview, and self-regulation. As a result, transparency becomes a critical issue for the governance of AT.

The lack of transparency in financial markets has been a hot topic globally in the last decade, and especially in the U.S. after the latest financial crisis in 2007-2009 (Hellwig, 2009). In the case of AT, transparency problems emerge through the combination of three factors – technological complexity, ultra-speed and financial innovation. In the first case, many have noted the “black box” character of financial algorithms. That is, while some financial algorithms are well known and widely used (e.g. the “Volume Weighted Average Price” or “VWAP” algorithm), others are protected as precious trade secrets (Lenglet, 2011; Pasquale, 2015). In addition, the speed and volume of information in addition also creates severe issues for transparency, and therefore rapidly increase the risks for governance failure. Zhang (2010), for example, notes:

[...] the non-transparency that stems from high-frequency trades (which can happen in milliseconds) makes tracking the trades virtually impossible. It took SEC [the Securities and Exchange Commission, our addition], which has unlimited access to data, more than five months to determine what caused the flash crash. (pp. 22)

See also Golumbia (2013) for a similar comment. As the financial data company *Nanex* notes, the faster financial information moves, the bigger data processing requirements are, and the slower surveillance activities becomes. Or put much more drastically:

Trading at the Microsecond Level: In one millionth of a second, nothing a human does consciously, can be measured. A quote can travel about 1000 feet (300m). A 1 Terabyte hard disk will store about 10 seconds worth of market data, which means you need over 2,000 disks to store 1 day. To receive market pricing information, you would need a terabit network, which is

currently a bleeding edge technology. You will be dead before the SEC finishes investigating an hour worth of data.

Quote from Nanex (2015, February 4). *HFT Doesn't Harm Investors and Other Absurdities*, Retrieved October 11th, 2016 from <http://www.nanex.net/aqck2/3532.html>

Lack of transparency is also the result of ingenious creations of new financial instruments created by financial actors themselves. In some cases, these are created to avoid political oversight. One clear example is the development of “swaps” in the 1990s in the U.S. as a means to avoid stricter government regulation of stocks and insurance products (Golumbia, 2013:12, Faiola, Nakashima & Drew, 2008).

Hence even though trades take place at hyperspeed, the secretive nature of certain types of financial algorithms, the massive amounts of data processed through financial systems, and continuous financial innovation, ironically makes oversight processes slow and challenging. As a response, policy makers and market actors try to gain control, implement decisions and learn from changing circumstances, by creating policies with the ambition to increase transparency.^{ix}

As Snider (2011) notes, real-time monitoring of trades through automated systems began already in the 1990s in the US. Systems such as these not only track trading activity, but are also designed to detect suspicious trading activities. The so called *2010 Dodd–Frank Wall Street Reform and Consumer Protection Act* brought considerable changes to the U.S. financial infrastructure, including policies to increase transparency and government supervision of financial instruments and markets across asset classes including commodities (Snider, 2011; Scopino, 2015).^x The 2010 “Flash Crash”^{xi}, led to additional proposals to further increase transparency from the U.S. Commodity Futures Trading Commission, and U.S. Securities and Exchange Commission (SEC)– two U.S. agencies whose actions have global financial repercussions.

In 2012, the U.S. Securities and Exchange Commission voted for the incorporation of a new system that will allow for better overview of trade data and hence help audit the extent and behavior of algorithmic trade.^{xii} Failure to comply has led to several occasions of punishment through fines. For example, on November 25, 2011, both CME and NYMEX fined *Infinium Capital Management* (Infinium) a total of \$850,000 for failing to supervise its Alternative Trading System (ATS), hence making disruptive high-speed trading more difficult to monitor (Scopino, 2015, p. 241). On March 25th 2015 SEC proposed a rule that would require high-frequency trading firms in “dark pools”^{xiii} to register with the Financial Industry Regulatory Authority, and submit a daily paper trail on their trading activities.^{xiv} The SEC has also proposed a consolidated audit trail (CAT), a multibillion dollar monitoring system (Keller, 2012, pp. 1479-1480).

The European Union has made several important advances in this regard as well. The Markets in Financial Instruments Directive (MiFID) and recent revisions in the new Directive (MiFID II) and a new Regulation (MiFIR) play key roles on this regard.^{xv} New legislation intends to increase transparency in so-called over-the-counter (OTC) derivatives markets by supporting the creation of a new breed of trading platform, known as an organised trading facility (or OTF). OTC derivatives markets cover trade with credit default swaps and interest rate swaps that are mainly traded bilaterally between the 15 top banks, with a value of up to \$640 trillion USD.^{xvi} In addition, firms engaging in AT will be required to notify its “Member State competent authority” of the firm’s activities and may, at any time, be required to provide details of the systems, strategies and controls it has in place. Trading venues will also be required to provide relevant authorities access to their order book on request so that the latter are able to monitor trading.^{xvii}

In Australia, increased transparency and hence overview has been assumed through the creation of a new market surveillance system with the capacity to analyze very large quantities of data as a means to avoid “flash crashes” and similar market events. It is notable that the monitoring system builds on the same sophisticated technologies and algorithms it is intended to monitor (Chesini & Giaretta, 2014).

Transparency is also seen as critical by actors at the supranational level, such as by the International Organization of Securities Commission (IOSCO). After a direct request from the G20, IOSCO presented a number of recommendations to market actors such as financial centers that would increase transparency and monitoring, including real-time monitoring and automated alerts (Chesini & Giaretta, 2014, p. 168; for details see IOSCO, 2011, 2013).

These new monitoring systems again build on the same sort of technologies it is intended to monitor, such as data mining, sophisticated statistics and artificial intelligence (Chesini & Giaretta, 2014, p. 182). The “algorithm arms race” in the financial sector hence unravels not only between financial firms, but also between the financial sector and policy-makers as the latter strive for transparency and oversight.

5.2. Slowing Down

Another form of governance intervention in hyperfunctional systems seems to focus on reducing speed (as elaborated in Partnoy, 2012). Slowing down hyperfunctional systems allows regulating actors to not only better monitor trading activities, but also to intervene by disconnecting parts of the systems of interest if considered needed (see more about this last step under “Decoupling”).

One example of this strategy can be found amongst private actors, such as the Brazilian stock market *Bolsa de Valores, Mercadorias & Futuros de São Paulo* (or BM&F BOVESPA). This market requests AT-firms to route their orders through a “pretrade risk tool” (Stafford, 2011; Mellow, 2014). A requirement such as this not only makes sure that errant buy or selling orders get filtered out before entering trade platforms, but also adds considerable latency (i.e. slows down the trading speed) for actors acting normally acting on the scale of microseconds (Holley, 2013).

As AT has made progression in other countries such as India, financial legislation has been changed to introduce “speed-bumps”, including leverage limits, securities transaction taxes (in 2004), and a basic levy for futures and options trade.^{xviii} In 2013 the Forward Markets Commission (FMC) in India announced its plans to put in place guidelines to oversee potentially adverse effects of algorithmic trade in commodity exchanges. Some of the measures include limitations on the possibilities for AT-firms to co-locate their servers next to the exchange’s servers, and fines in cases where orders do not lead into actual trade thereby reducing both speed and the volume of information entering the exchanges.^{xix}

Policy-makers in *China* have implemented similar measures that not only put a fee on transactions, but also limit the velocity of trade by for example forbidding the sale of a stock that was bought the same day (the so called T+1 rule).^{xx} Each of these mechanisms contributes to a reduction of trading volume information, and increase the average trading time, a critical parameter for AT-actors that tend to trade in very large volumes quickly.

European legislators have explored other strategies to slow down financial markets – e.g. the possible creation of a “half-second rule”. This proposed rule would force AT actors to maintain their market orders for at least 0.5 seconds. Such a rule would in principle filter away AT-driven orders that move in and out of stock exchanges (note that the current time span for such

movements is below 5 microseconds [0.005 seconds]). The European Parliament supported the rule officially in September 2012, but the rule was later dropped after negotiations between member states and private actors.^{xxi} However, new pieces of European legislation in MiFID2 require algorithmic traders to register their formulae with regulators. It should be noted that the final approval of MiFID2 was only achieved after tough negotiations between European states with clearly conflicting views on the matter.^{xxii}

Key agencies in the United States have also at several occasions attempted to advance policies that would slow down the flow of financial information. A joint SEC and CFTC committee in 2011 (CFTC-SEC Advisory Committee 2011) proposed restrictions on co-location (pp. 7f) and penalties for rapid order cancellation (pp. 11). These proposals in combination would help slow down financial information flows. However, these have yet to be implemented and seem to be halted by existing tensions between legislators and the private sector.^{xxiii}

5.3. Decoupling

The last strategy is related to policy interventions aiming to strategically reduce connectivity by decoupling different parts of the system (sometimes denoted as “circuit breakers”, or “breaking points”). The goal here is to mitigate networked vulnerabilities, and reduce the possibilities of cascading failures as different parts of financial markets become increasingly connected (e.g. stock and commodity markets), or as financial innovations and actors start to penetrate other parts of the economic system (for an elaboration of the implications of such networked risks, see Helbing, 2013; May et al., 2008).

In 2014 the European Parliament adopted a first draft legislation based on the Markets in Financial Instruments Derivative (MiFID), attempting to constraint what is perceived as “harmful speculation” by proposing so called “position limits”. This refers to limits to the number of contracts in a particular commodity that can be held by a trader, or group of traders. The intention is to keep certain types of financial actors away from agricultural commodity markets as they may contribute to price volatility.^{xxiv} Legislation targeting algorithmic trade in particular has also been adopted by the Parliament in October 2012, and January 2014 (MiFID2).^{xxv} MiFID2 also requires trading venues to introduce a so called a ‘kill button’ – mechanisms that temporarily halt trade in an exchange or in one stock if it falls a certain pre-defined percentage.

The joint U.S. SEC and CFTC committee in 2011 not only proposed interventions to slow down flows of financial information, but also updated protocols for “circuit breakers”^{xxvi} targeting AT. The committee based this proposal on a previous private-public pilot project including only a subset of securities (e.g. securities included in the S&P 500 Index), and called for an extension for larger segments and financial instruments in the market (SEC-CFTC Advisory Committee 2011, pp. 3f). Again, these measures have yet to be implemented.

5.4. Fighting Back

Needless to say, all these initiatives with the ambition to increase transparency, decouple and slow down are highly conflictive, and have led to intense debates between policy-makers, representatives from a diversity of financial actors including banks and stock exchanges, and non-governmental organizations. In the U.S. for example, lobbying efforts by Wall Street banks such as Goldman Sachs have been intense with the ambition to influence the details of the rules in such a way to keep lucrative trading practices unregulated or at least self-regulated (Snider, 2011,

p. 12; see also Valdez, 2015). The number of European policy initiatives elaborated above have also led to intense negotiations between member states, but also concerns from associations such as The British Bankers' Association who described parts of the legislation as "particularly onerous".^{xxvii} In contrast, U.S. federal courts have rejected the proposal on so called "position limits", inducing new rounds of still ongoing debates and legislative processes.^{xxviii} Even the mere definition of what actually entails as "high frequency trading" is debated and contested (Patterson & Strasburg, 2012). Hence while these measures might seem logical from a governance point of view, they do not come easy in a sector here decision-making is diffuse, large amounts of capital are at stake, and where causality is complex and highly contested.

6. Conclusion: Complexity Governance in an Ultrafast World

As we have elaborated in detail in this article, the progression of AT in financial markets provides a number of interesting insights into the governance of complexity, but complexity of a very specific sort: superconnected, hyperfunctional, and ultrafast. As a response to the first question posed in the opening of this paper, AT is a new type of phenomenon in financial and commodity derivative markets, defined by atomistic behavior resulting from human-computer interactions, extremely high speed of transactions and a global reach. It is interesting to note that some accounts of financial management dysfunctional behavior in the 1980s and early 1990s (e.g. Davis, 1998; Krugman, 1994) appear as rather innocent financial extravagancies compared to some of the more extreme pathologies that can be associated with uncontrolled AT. This calls for theoretical approaches that acknowledge this complexity, emerging phenomena such as hyperfunctionality, surprise and propagating shocks, and that explore novel ways to address these risks.

As we have elaborated, AT challenges simple notions of agency in financial market decision-making. For example, the fact that the dynamics of financial systems are to such large extent driven by the interplay between human action and algorithms flies in the face of most conventional models of governance, where deliberation, interaction, reciprocity and consent are seen as integral to the organization and pursuit of collective action (e.g. Koppenjan & Klijn, 2004; Colander & Kupers, 2014; Duit & Galaz, 2008; Pierre & Peters, 2005).

The "normal state of affairs" in economic governance, as it has been conducted in the advanced western democracies over the past several decades, is characterized by the pursuit of the "sweet spot" between articulating collective interests in the market without distorting the allocative mechanisms in that market. In many countries this governance is conducted through extensive social consultation and deliberation in order to allow for external input, and generate consent and legitimacy for the economic policy. As we have discussed in this article, AT is alien to this conventional governance arrangement.

Focusing on the governance aspects (and as a response to our second question), AT forces us to re-evaluate existing theoretical approaches and what we perceive as key functions in governance. AT seemingly changes the nature of economic governance from a pro-active to a reactive ("negative") governance where accommodation and damage control seems to take precedence over future-oriented policy. Whether this hypothesis holds over time, and in the face of additional empirical analysis from more countries and markets, is a critical research question for the future.

Hyperfunctionality is an additional key issue to explore in this regard. Governance failure is usually associated with non-functioning or malfunctioning systems or institutions (Peters &

Pierre, 2015). In our view, AT's hyperfunctionality is a governance problem, more than it is a technical or legal problem. AT thus provides an excellent example of globalization processes combined with rapid technological development, and a lagging regulatory response. Once the regulatory process has caught up with the dysfunctions of AT, new technological advances will most likely have created new technologies or financial innovations that evade the regulations. Governance hence remains a central issue, and ultrafast systems of this sort forces us to ask how to ensure that the financial market is brought back into "sync" with other components and subsystems in the economy. However, such governance will by necessity be networked. The reason is the distributed nature of the issue spanning over multiple sectors, types of actors, and geographical political boundaries.

This brings us to our third question about current governance responses. The responses explored here – transparency, slowing down and decoupling – show the emergence of new strategies assumed by multiple governmental and non-governmental decision-makers facing the risks entailed with ultrafast and superconnected systems. These responses are distributed across a number of governmental and private actors, at times converging into networked or loosely coupled polycentric responses as actors continuously adjust to each other's behavior (as explored by Galaz, Crona, Österblom, Olsson & Folke 2012 for polycentric coordination at large scales). While distributed, these initiatives strategically target key parameters in the system of interest as a means to make the AT at all governable, by influencing information content and volume and the technological infrastructures that create connectivity and superspeed.

Whether these strategies will prove successful, to what extent these governance networks will emerge and prove robust, and whether political actors have the resources and technology to enforce these rules in multilevel governance settings (i.e. ranging from national to transnational settings), remain critical research questions. Lessons from the financial sector explored here could, in the meantime, prove very valuable as governance scholars continue to explore emerging governance responses and failures in a hyperconnected world.

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Endnotes

- i It should be noted that the definition of AT in itself is highly contested. Here we define algorithmic trade (AT) as trade that relies on high-speed computer linkages; uses of sophisticated statistical, econometric, machine learning, and other quantitative techniques; and cases where traders hold positions for very short periods of time (micro-seconds) (Government Office for Science (GOS), 2011, p. 28; US Securities and Exchange Commission, 2010; Hendershott, Jones, & Menkveld, 2011, p. 1).
- ii Note that these four examples are simplifications. For a more detailed description of different trading strategies and types of models, see Narang (2013).
- iii The recent debate spurred by Lewis' book "Flashboys" (2014) is a good illustration of this challenge. The book triggered intense criticism from financial experts and commentators, See for example Narang, M. (2014, April 4). A Much-Needed HFT Primer for 'Flash Boys' Author Michael Lewis, *Institutional Investor*. Retrieved October 11, 2016,



from http://www.institutionalinvestor.com/Article/3328158/Banking-and-Capital-Markets-Trading-and-Technology/A-Much-Needed-HFT-Primer-for-Flash-Boys-Author-Michael-Lewis.html#_U6ygpI1dWJg; Weil, Jonathan (2014, April 1). Weil on Finance: FBI Hops on Michael Lewis Bandwagon, *Bloomberg News*. Retrieved October 11, 2016, from <http://www.bloombergvew.com/articles/2014-04-01/weil-on-finance-fbi-hops-on-michael-lewis-bandwagon>; Bradford, Harry (2014, April 1). FBI Investigating High-Frequency Traders. *Huffington Post*. Retrieved October 11, 2016, from http://www.huffingtonpost.com/2014/03/31/fbi-high-speed-trading_n_5065622.html

- ^{iv} See for example <http://www.algotrader.ch/> or <https://www.quantopian.com/> which even hosts competitions as a means to crowd source hedge funds' algorithm based strategies.
- ^v BBC News (2011, November 18). 'Lightning fast' future traders working in nanoseconds, Retrieved October 11, 2016, from <http://www.bbc.com/news/business-15722530>
- ^{vi} CNBC (2013, July 24). Buying an edge: The high-tech race for economic data pays. Retrieved October 11, 2016, from <http://www.cnbc.com/id/100910912>
- ^{vii} It should be noted that the actor landscape is considerably more complex and also involve actors such as commercial banks, investment banks, mutual funds, pension funds, venture capital, and others. For simplicity, we only focus on major governmental and private responses.
- ^{viii} The summary builds on a combination of secondary literature, reports from prominent organizations, and news articles as a way to get as rich of a picture as possible of unfolding and highly fluid governance efforts. It should be noted however that our ambition is not to present *all* private and public regulatory responses to AT the last decade. Not only would such a synthesis exceed the word limitations of an article, but it would also distract us from making our key argument.
- ^{ix} It should be noted is that our summary below includes policies that are proposed, and others that already are in effect. We have included both these categories to show the rapid evolution of policies, and how these match the identified governance activities (increasing transparency, slowing down, decoupling). Our summary also includes policies and proposals from different parts of the world to illustrate the global scope of these governance attempts. However, our ambition has not been to create an all-encompassing list of regulation, but showcase a number of important policies as identified in secondary literature.
- ^x Bloomberg Business (2010, October 12). CFTC to Scrutinize Algorithmic Trading After May Market Plunge. Retrieved October 11, 2016 from <http://www.bloomberg.com/news/2010-10-12/commodity-regulator-to-review-algorithmic-trading-after-may-market-plunge.html>
- ^{xi} The "Flash Crash" is the term for a rapid crash on May 6th, 2010, when the Dow Jones Industrial Average dived about 1000 points, only to recover within minutes. (US Commodity Futures Trading Commission, & US Securities and Exchange Commission, 2010).
- ^{xii} High Frequency Traders (2012, July 13). SEC votes in favour of high frequency trading audits. Retrieved October 11, 2016 from <http://highfrequencytraders.com/news/2379/sec-votes-favour-high-frequency-trading-audits>
- ^{xiii} "Dark pools" are electronic trading venues that don't display public quotes for stocks. These "pools" anonymously match orders of bigger investors with the ambition not alert the wider market of their intentions. Estimates show that there are about 40 dark pools operating today, and include venues such as Luquidnet, Goldman Sach's Sigma X and Credit Suisse's Advanced Execution Services (from McGowan, 2010, see also Banks, 2010).
- ^{xiv} New York Post (2015, March 25). SEC chair takes aim at predatory traders in 'dark pools', Retrieved October 11, 2016 from <http://nypost.com/2015/03/25/sec-chief-takes-aim-at-predatory-traders-in-dark-pools/>
- ^{xv} Formally the final MiFID II and MiFIR texts were published in the Official Journal of the EU (OJ) on 12 June 2014 and entered into force 20 days later on 2 July 2014. Entry into application will follow on 3 January 2017. Source: Norton Rose Fulbright (2014, October). MiFID II / MiFIR series. Retrieved October 11, 2016 from <http://www.nortonrosefulbright.com/knowledge/publications/115236/mifid-ii-mifir-series>
- ^{xvi} Source: Reuters (2014, January 14). EU reaches deal on sweeping securities reform. Retrieved October 11, 2016 from <http://uk.reuters.com/article/2014/01/14/uk-eu-mifid-idUKBREA0D1MA20140114>
- ^{xvii} Source: Norton Rose Fulbright (2014, October). MiFID II / MiFIR series. Retrieved October 11, 2016 from <http://www.nortonrosefulbright.com/knowledge/publications/115236/mifid-ii-mifir-series>

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- ^{xviii} Institutional Investor (2015, June 9). High Frequency Trading gets a Mixed reception in Emerging Markets, 2015-06-09. Retrieved October 11, 2016 from: http://www.institutionalinvestor.com/article/3349687/asset-management-equities/high-frequency-trading-gets-a-mixed-reception-in-emerging-markets.html#.VRWifGTF_7c
- ^{xix} The Economic Times (2013, February 1). Forward Markets Commission lays down stringent norms for algorithm trades, Retrieved October 11, 2016 from: http://articles.economictimes.indiatimes.com/2013-02-01/news/36684553_1_forward-markets-commission-algos-high-frequency-trades
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- ^{xxi} Reuters (2013, October 22). EU agrees preliminary deal to rein in speed traders. Retrieved October 11, 2016 from <http://www.reuters.com/article/2013/10/22/europe-speedtrading-idUSL5N0IC1NH20131022>
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