Algorithms and the Anthropocene

Finance, Sustainability, and the Promise and Hazards of New Financial Technologies

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Abstract

This paper addresses how high frequency trading in financial markets is increasingly discursively related to climate change and producing peculiar iterative patterns of accommodation and reinforcement of climate change. Stock market trades have accelerated at a rate at which shares change hands in microseconds. This increases the risk of systemic crises. I examine the ways in which high frequency trading both reconfigures the dynamics of finance and changes the global financial system in different spatio-temporal ways, as well as produces political ecologies of engagement, divergence, and convergence between the financial and Earth Systems. Accordingly, I examine technological change and algorithmic strategies at stock exchanges. By analyzing algorithmic strategies, I interrogate the connections between algorithms at stock exchanges and the environment, and how algorithmic financialization intersects the Anthropocene debate. The analysis explains the nature of high frequency trading strategies and market responses to natural disasters, tsunamis, typhoons, draught and wild fires. In the final section, I discuss whether algorithmic economies singularly contribute to worsening environmental crises and how financial investment algorithms may adapt to climate change.

Key Words: Anthropocene, Financial Markets, Climate Change, Algorithms, Technology, Nature and Space, Natural Disasters, Relational Economic Geography

Introduction – Divergence and convergence between the financial system and Earth system

This paper examines the convergence and divergence between global environmental change (whether anthropogenic or not) and natural disasters, such as tsunamis, typhoons, draughts or wild fires, and algorithmic strategies at the global financial markets. In demonstrating the space-time structure of high frequency trading (HFT) from the perspective of economic geography, I explore informational technology aspects of financialization to identify the nexus between environmental disasters and ways in which financial algorithms (HFT) relate to climate change. In doing so, the study addresses the following questions: How do different spatio-temporalities affect the carbon-capital relationship? When the rate of finance capital transactions accelerates, do human-environmental interactions accelerate as well? How do trading algorithms respond to climate change and natural disasters? And, ultimately, with respect to the Anthropocene-at-risk, how does the co-construction of markets and nature through algorithmic financialization disproportionally impact the most vulnerable regions and communities in the world?

As the atmospheric CO2 concentration surpasses 410 PPM, carbon dense assets remain a profitable business. Carbon dense assets are assets that are energy dense and fundamentally rely on fossil fuels and high-energy consumption/production per unit, but do not reflect the external costs of carbon. In the fiscal year 2017 the world's ten most revenue generating companies include five oil, coal and gas producers and two automobile manufactures: State Grid Corporation of China, Sinopec Group, China National Petroleum Corporation, Exxon Mobile, Royal Dutch Shell, Volkswagen and Toyota. Listed at the world's largest stock exchanges, they generated a total combined revenue of $1,786 billion (Fortune, 2017). While fossil fuel suppliers faced decreasing revenues in recent years, in competition from suppliers of renewable energy sources, carbon-demanding companies, including the automobile industry, have displayed better revenue results, in part due to the favorable price structure of fossil fuels. Traded daily in high frequency, these carbon-dense assets reveal both the political and technological importance of market-driven mechanisms (such as the Clean Development Mechanism), which politicians and states anticipate could address climate change (Knox-Hayes, 2013). The Paris Accord reinforces the idea of market-driven mechanism (Schneider et al., 2016). The accord gives each individual country full freedom to determine its commitments (nationally determined contributions, NDC). Hereby they rely on globally available mitigation options. Insofar as governments can access cheap mitigation, they may be willing to raise their NDC. Thus, the architecture of the Paris Accord gives market mechanism much greater importance than under the Kyoto Protocol, and reserves a full article (article 6.4) to market mechanism (Stavins and Stowe, 2017). In parallel, as market-based governance systems gain dominance in the fight to reduce carbon emissions, the global financial system has experienced significant spatio-temporal changes that have an ever-increasing bearing on climate change.

Today equities change hands, by the grace of information technology, in fractions of a second and approximately half of the daily trading volume in US stock markets is performed in high frequency. HFT refers to algorithmic technologies by which trading decisions are automated and executed by machines at a speed at which no human trader can possibly follow or intervene (Brogaard et al., 2014). In essence, HFT is non-human trading in sequences: sequences in which algorithms take economic decision on timing, price and execution of orders, in accordance with the interests of the owners of the means of production (Grindsted, 2016). With profit as the single core objective, high frequency equities trading is durably reproducing and perpetuating, if not also intensifying, patterns of investment and exchange that deepen social-economic inequality globally. How this techno-financial modus is co-constructed with the global environment is largely unexplored in the nature-society literature.

The analytical heart of the paper is located within critical debates on the Anthropocene as it identifies how technology has, effectively, weaponized finance capital in ways that threaten global environmental sustainability, and by extension, have sharpened the social divide between places of prosperity and places of exclusion. I employ the concept of relational economic geography (REG) to illuminate and analyze complex economic, social, organizational, and technological relations, with respect to the relationship between HFT financialization and environmental change and hazards, by laying bare the interactions among them (for example, I explore localized consequences of economic decision-making) (Bathelt and Glückler, 2003).

While geographies of finance cover a vast spectrum of fields, including investment banking (Wójcik, 2012), hedge funds (Teo, 2009), finance and the housing crisis (Martin, 2011), carbon markets (Knox-Hayes, 2013) and financialization of the environment (Bergmann, 2017; Loftus, 2015), little research has been undertaken with respect to the divergence and convergence between algorithmic economies and the critical environmental and social dimensions of the Anthropocene. Yet, relations between the accelerating financial and deteriorating Earth systems are constituted in ways in which the carbonization of the atmosphere emerges as paradigmatic of them (Cooper, 2010).

The paper is divided into five sections. Drawing on David Harvey's Justice, Nature and Geography of Difference (1996), I explain in the first section the rise of HFT, focusing on three performative dynamics: the increasing demand for pension funds, the constitutive relationship of technologies in structuring economic markets, and the regulative transformation of such markets. I then review critical studies on finance and high frequency trading to elaborate an economic geographical framework of algorithms in space-time. Third, the paper addresses the spaces of transaction, and the ways in which environmental market information both alienates from and constitutes markets. Further, I demonstrate how algorithmic strategies react to natural disasters. In the final section, I discuss how algorithmic strategies perform peculiar forms of adaptation to climate change by managing risk in ever-smaller time fractions. Acceleration of financialization in scale and time (outwards as well as inwards), reconfigures the dynamics under which a resource is considered to be profitable or not. That is, the extent to which natural resources and environmental phenomena are valued to be profitable in any given time-scale ratio. Hence, the techno-financial acceleration of portfolio management adapts to climate change by aiming at minimizing risks, while deepening and widening the social and natural disasters caused by climate change when speculating on them. When finance speeds up, do human-environmental interactions follow? And if so, what are the risks especially for vulnerable places and communities in the Anthropocene?

Time space compression and the rise of algorithmic trading

As computer-based trading connects the global financial market more densely than ever before, the capital accumulation-based economy enters a new era facilitated by deregulation and information technologies. Accordingly, the markets are in continuous structural flux. Their changing character embodies new temporalities: To paraphrase Harvey's classic dictum concerning the annihilation of space by time (Harvey, 1989, p. 240), financial firms implode the temporal dimensions of the financial trade into ever diminishing fractions to gain ground in the market.

New spatialities are also emerging as a result of the installation of ultra-fast fiber optic data connections between trading houses and financial exchanges. They complement and accelerate more familiar data, decision-making, and capital flows that have defined networks of global cities since the mid-1980s. Consider the laying out of an 827-mile ultra-fast fiber optic data connection linking, in a perfectly straight line, a data exchange in South Chicago to a similar exchange in Northern New Jersey. The contractor Spread Networks boasted that "[r]ound-trip travel time from Chicago to New Jersey has been cut 13 milliseconds" (Lewis, 2014, p. 15). The project begs comparison to the 1853 Chicago-New York railroad route established by the New York Central Railroad Company in 1853. The 21st century link sends electrons instead of people, parcels, and assorted freight.

The time-savings allow the firms who subscribe to the service to beat their competitors to a market – in this case, a market that involves Chicago's lucrative commodities and options markets. From a critical perspective, it is difficult to see this maneuver as anything but a legal version of rigging the market for the firms that can afford the service. Further, massive amounts of capital are being shifted to infrastructure projects of the sort that benefits the financial exchange economy while the hardscape infrastructure of bridges, tunnels, roads, water and sewage networks are starved of investment. Ultimately, HFT becomes one more structural and strategic imperative of the neoliberal state that marginalizes places and communities disconnected from globally situated industries of capital accumulation.

Geographies of finance, then, are vital to the rise of HFT due to the design of "continuous" trading, such as arbitrage trading. They are based on informational advantages constituted via the spatio-temporalities of market actors and their relational geography (as in the case of the service provider Spread Networks) (Zook and Grote, 2017). For this reason, space-time compression, or what I would call space-time implosion, becomes of crucial importance to understanding the radical new dynamics in financial markets – but also more broadly – to understanding the dynamics of contemporary finance-driven accumulation regimes.

What is different from other electronic trading is not only the astonishing speed at which trading takes place. It is also the ability to carry out thousands of orders within microseconds, and to use financial news and key reports before everyone else (Groß-Klußmann and Hautsch, 2011). Algorithms are also able to foresee other traders' bids and limit orders before their trades are executed. Algorithms are able to take into consideration small variations in price of a particular share traded on different markets simultaneously and precipitate, cumulatively and over time, market actions that may have far and wide implications on the lives of communities and the sustainability of places.

During the past decade, technological innovations have allowed the temporalities of stock exchange transactions to accelerate to such a rate that milliseconds have become critical to profitable trading (Menkveld, 2011). Electronic trading, however, is nothing new. In 1971 NASDAQ became the world's first electronic stock market and five years later, the New York Stock Exchange (NYSE) introduced the so-called DOT system (Designed Order Turnaround system) that allowed securities to be traded electronically (McGowan, 2010). Authorized by the U.S. Securities Exchange Commission (SEC) HFT débuted in the market in 1999. HFT did not receive much attention among economic geographers or economists at the time. Even within the financial sector, HFT was given little priority until late 2008, simply because it was considered a niche strategy (MacKenzie et al., 2012). In few years however, and parallel with the global financial crisis, HFT turned from a niche strategy into a lucrative industry (Brogaard et al., 2014). Structural requirements for algorithmic strategies kept them a niche strategy for a while - not so much because of the lack of technological advancement, but because of de-regulatory change (see next section).

By the 2000s, international exchanges gradually adopted algorithmic trading. Especially US and EU legislation paved the way for algorithms exchanges and legislators around the globe followed. The trading volume of stock exchanges first grew in the US and Europe, then spread to Asia, Japan and South America. The structural importance of HFT is global in character. Registered exchanges worldwide are reconfigured by HFT algorithms, be it Tokyo Stock Exchange (Hosaka, 2014), New York, Shanghai, Sao Paulo or London (Buchanan, 2015).

Today, approximately half of the daily trading at all stock exchanges in the US is performed by HFT, according to the TABB Group (Bullock et al., 2018). Similarly, HFT dominates daily trading at European stock exchanges, reportedly up to 77% in the UK (Menkveld, 2011). News sources and reports from key financial institutions and journals demonstrate, however, that reporting of trading volume in HFT varies significantly (figure 1) and displays data controversy over the volume of HFT trading. By way of illustration Bloomberg (2013) reports, "as much as two-thirds of all stock trades in the U.S. from 2008 to 2011 were executed by high-frequency firms; today [2012-2013 red.] it's about half" (Philips, 2013). By contrast, Wall Street Journal

(2012) suggests, with data from Morgan Stanley, that HFT makes up 84 % of the US trading volume in 2012 (Lewis, 2012). Data controversy exists to the extent that data from the same company or journal contradict each other. By way of illustration, data from TABB group suggest that the volume of HFT trading as a % of all US equity trading in the US, is 61% in 2009 in one source (Na, 2012) and 34 % in another (Vlastelica, 2017).

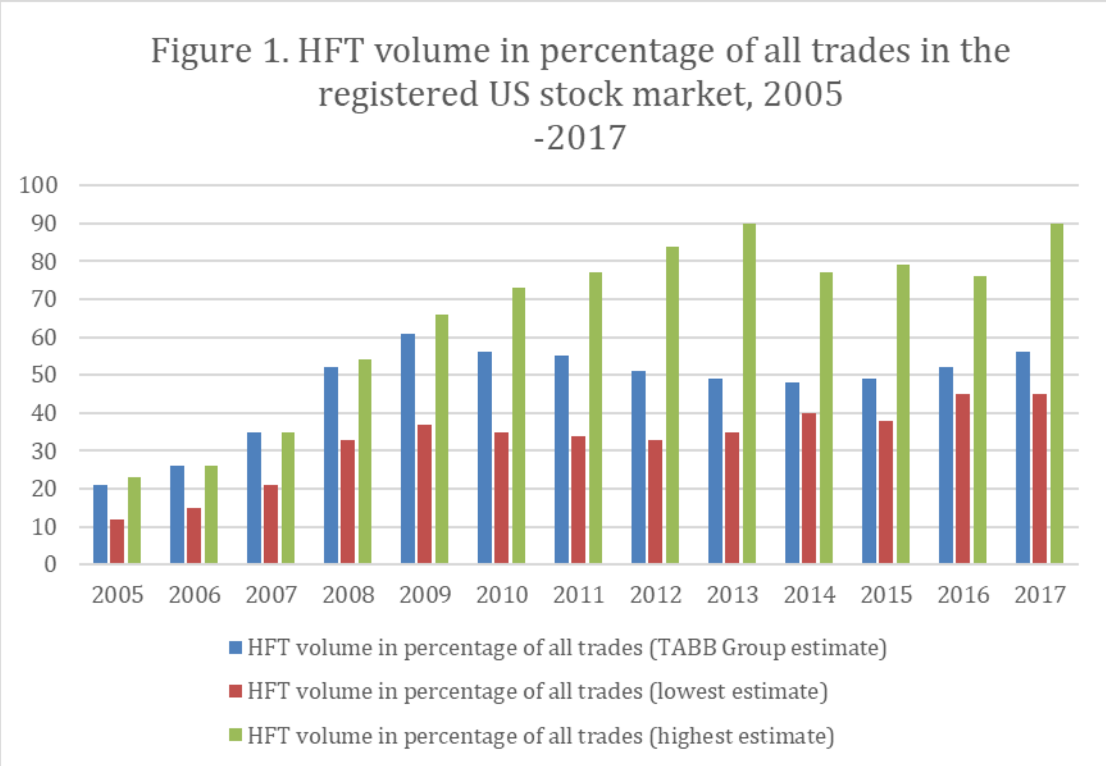

Figure 1. HFT volume in percentage of all trades in the registered US stock market, 2006-2012. Source: (Avellaneda, 2012; Brogaard et al., 2014; Bullock et al., 2018; Cheng, 2017; Demos, 2012; Lewis, 2014; Lewis, 2012; MacKenzie et al., 2012; Massa and Mamudi, 2017; McGowan, 2010; Menkveld, 2011; Miller and Shorter, 2016; Na, 2012; Philips, 2013; Rupp, 2013; Sornette and Becke, 2011; Vlastelica, 2017; Woodward, 2018).

Two observations are relevant to the rise of algorithmic trading and the continuing controversy of conflicting figures reported. First, during the global financial crisis, the volume of daily average trade in the US dropped by 30%, from 9.8 billion shares in 2009 to 6.4 billion in 2012 (Rupp, 2013). The relative decline of the HFT volume in figure 1, despite controversy, does not demonstrate a similar decline. Second, as HFT began to dominate the stock exchanges, traditional large institutional and corporate investors, such as pensions and hedge funds, sought to avoid these value skimming algorithms (Lewis, 2014). Thus, hedge and pension funds turned into 'dark pools' and internalized orders. Dark pools are private exchanges run by big brokers, whereas traditional stock exchanges represent market information in publicity. In dark pools, one needs to neither indicate identity nor disclose the volume of trade. The ideology brought in here is that transparency is an enemy to big traders, since when executing large orders everyone will know they enter the market, and speculate against them (Sherman, 2009). The reverse strategy, that big traders speculate on affecting market prices, however, is also true. Nonetheless, these over the counter (OCT) practices have grown significantly during the last years and hence the algorithms have followed. Thus, one third of equity trading is executed outside registered exchanges. While daily trading at registered exchanges declined approximately 30 % from 2009-2012, much is absorbed in dark pools and internalized trades.

As controversy over HFT grew, so did the controversy over representing algorithms and their widespread effects. Haraway's (2015) "chthulucene" applies, assembling the earth-wide technological-disruptive powers across time spaces, forces and intra-active entities-assemblages (including more than human) that also collect the webs of speculative fabulation, science fiction and scientific fact. The algorithmic chthulucene tell the stories of their own. Because the actions of HFTs are so difficult to track, Golumbia (2013) argues, it assembles an overload of untraceable information (e.g. when placing orders and removing them) that have the purpose to serve particular agendas, while it concentrates power, becomes more opaque, and less subject to democratic oversight. Much of what we see (the market price that is offered to me as a citizen, I have no clue of fluctuations in microseconds) is tailored for and aimed at users from the perspective of those in power, deliberately hiding its most potent effects from us. Thus, algorithms hide away the important operations and their effects e.g. to the anthropocene. As Haraway notes, "It matters which stories tell stories, which concepts think concepts. Mathematically, visually, and narratively it matters which figures figure figures, which systems systemic systems" (Haraway, 2015, p. 160). The ways in which global environmental change and algorithms interact are anthropocene/capitalocene/chlutucene in its entirety, through the scale, rate/speed and synchronicity and complexity, exchanges take place and their effects mediated, "Mathematically, visually, and narratively" (Haraway, 2015, p. 160).

Algorithmic financial geographies and the value of a microsecond

Deregulation has been critical for the security industry and the evolution of high frequency trading. Deregulatory actions from 1986 onward resulted in the repeal of the Glass-Steagall Act (1933) and the Securities Exchanges Act (1934). The removal of Great Depression-era protections allowed commercial banking to merge with the credit and securities industries. In combination with the US Commodity Futures Trading Commission (CFTC), The Regulation National Market System (Reg. NMS) and the Markets in Financial Instruments Directive (MiFID) in the EU and equivalent regulation, paved the way for algorithmic trading that potentially came to simultaneously control supply and demand (Sherman, 2009).

In 1996, the Federal Reserve, allowed bank holding companies to own investment banking operations and from then on, it only took three years to repeal the act and passage the Commodity Futures Modernization Act in 2000 (Sherman, 2009). In effect, the obligatory separation of commercial banking, into the security industry and the credit sector were now merged for the first time since 1933 (Sornette and Becke, 2011). Passed by the Congress, with minimum debate and review, the Commodity Futures Modernization Act prevented the CFTC to reregulate most derivate contracts, including credit default swaps, creating the prevailing paradigm of self-regulation. As a result, the completely unregulated derivatives trading increased from $106 trillion in 2001, to $531 trillion in 2008 (Sherman, 2009). The geographical expansion of trading possibilities first spread from the US to the UK, from where the liberalization of security trading was expanded to the EU with the Investment Services Directive (ISD) in 1996 and the Financial Instruments Directive (MiFID) in 2007 (Wójcik, 2012, p. 358).

Algorithmic technologies along with Information and Communication Technologies (ICT) and Electronic Communication Networks (ECN) facilitate ultrafast transactions. Finalized through the Alternative Trading System (Reg. ATS) by the US Security Exchange Commission (SEC) in 1998 ECN's allowed trading outside the traditional stock exchanges (McGowan. 2010). Eventually, computer operations that facilitated execution of orders by algorithms came about. Financial deregulation allowed investment banks, hedge funds and the security industry to make use of the new technologies (Wójcik, 2012). In addition, the Regulation National Market System (Reg. NMS) was an influential deregulatory factor that opened the way to HFT. Reg. NMS were authorized by SEC in 2005 with a range of initiatives that required market orders to be immediately electronically executed (Menkveld, 2011). While the Pre Reg. NSM matched orders in temporalities of seconds and minutes, the Reg. NMS put advantage in matching orders in microsecond and conveyed the structural advantages for current electronic trading. The last element of deregulation that hugely influences technological advances, significant to the introduction of HFT, is the so-called "decimalization" Act from 2001. This made algorithmic capitalization lucrative, since it also changed the profitability time-ratio as it was regulated from 1/16th of a dollar to $0.01 per share. "Overnight the minimum spread a market-maker stood to pocket between a bid and offer was compressed from 6.25 cents…down to a penny. This move decreased a market-maker's trading advantage and led to increased liquidity which in turn eventually led to the current boom in algorithmic trading" (McGowan, 2010, p. 34). Deregulation fueled the most fluid and mobile form of money capital - that quickly relocates geographically. Thus, algorithms provide an example of the political effects of finance driven activities, and their seemingly discrete social effects. I will examine two examples of the performative dynamics of algorithms and the Anthropocene in the next section.

Consider, for instance, the huge demand for pension funds and the routine actions undertaken by the broker, dealer, or agent who manages such a fund. The standard modus includes purchases and sales of equities, bonds, or other financial instruments on behalf of clients. With a few keystrokes and in a second (or less) of time, the client would own a piece of the real economy somewhere in the world. At that point, the client data would flow through the browser operator's servers and convert into 'insider knowledge' – it would become part of the master epistemic framework of the economy, and by extension, the "Capitalocene" – the era and the world that late finance capitalism are shaping. As the agent is placing the order, algorithms forecast the trader's intentions because they draw on calculations of the bids and limits of pending orders. Through their ability to place thousands of trades per second, possess panoramic views of financial data, and calculate insights about them, algorithms are able to buy or sell shares before the traders, affecting the price of financial instruments in microseconds.

Potentially algorithms surveil standing orders and client profiles during the simultaneous act of buying and selling financial instruments. Accordingly, the intermediate financial firm and the investment banking industry in general, which should act in the service of the interests of its clients, may, instead, speculate against them. By way of illustration, if an equity has a present market value of USD 20.01 and the client imposes a limit order at USD 20.02, algorithms possess the information necessary to sell up to USD 20.02 and appropriate the difference (IOSCO, 2011). This is the so-called "front running trick." Algorithms act as buyers and sellers: for example, they simultaneously trade the same security at both sides of the transaction, and earn money on the spread (MacKenzie et al., 2012). This applies to what a typical human market maker would do as well, but the difference is the astonishing speed at which this is done. This gives a strategic advantage compared to traders operating at a lower temporality. Other strategies that algorithms can perform are, for example, "piggy backing," "riding on waves," "layer by spoofing," or arbitrage strategies (Sornette and Becke, 2011).

The spatio-temporal market information dynamics of such practices are of considerable interest to us. When algorithmic strategies exploit knowledge in financial markets not only speed but also expansion between different temporalities is of interest (Grindsted, 2016). E.g. By 2001, HFT trades had an execution time of several seconds. By 2010, this had shrunk to milliseconds, even microseconds, among others driven by the "decimalization" Act (Sherman, 2009). In HFT, the value of speed relies on access to market information before competitors get to mine and exploit it. The advantage of speed supports Michael Lewis' claim that the entire existence of HFT depends on being faster than the rest of the stock market (Lewis, 2014, p. 14). What is sold, in this case, is essentially speed or access to 'free market information' before it can be accessed by competitors. If speed is traded, it only has value to the extent it is a scarce resource. Algorithmic capitalism (Grindsted, 2016), an essential component of the Capitalocene, therefore, refers to the process whereby the value of speed is essential to appropriate value out of other transactional processes through the construction of spatio-temporal information inequalities (as the case may be, giving rise to ephemeral monopolies to the firms, which can acquire the underlying technologies and service contracts). Further, if it is time that is traded, then it is fundamentally contradictory to the use value of products it relies upon. Now exchange value has taken form as also temporal exchange value, simply because this information has only value in milli- and microseconds. Therefore, arbitrage strategies illustrate the spatio-temporalies of HFT perfectly well.

Consider an Exxon Mobile share simultaneously traded at multiple stock exchanges around the world. Assume that the Exxon Mobile equity has a present value of USD76.60 at the Chicago Stock Exchange (CHX). Imagine the same share is traded at the New York Stock Exchange (NYSE) at USD76.50. In the case of price difference between the same shares traded at different stock exchanges, arbitrage algorithms take advantage of that market information. To gain full advantage of the price gap, one needs to be the first to react by placing an order at NYSE and selling the very same share at the higher price at CHX, before other algorithms level-out the price-locational difference. The gambit is being faster than competitors that either do not know or do not possess the technology that enables them to take advantage of the spatio-temporal information inequality (Zook and Grote, 2017).

Ultrafast reaction time, therefore, has a spatial dimension, and what matters is the distance from the servers to the matching engines, as was also indicated by the Spread Networks' fiber optic line project linking Chicago to the outskirts of New York City.

The ability of market competitors to receive 'free market information' flowing between information source and information consumer, in milliseconds, microseconds or seconds, is contingent upon the technologies used, traders' location relative to the match engines (servers), as well as the distance to other traders. Or it is, simply, contingent upon the firm's ability to buy 'first access packages' (MacKenzie et al., 2012). As traders' access to free market information is relative to the geographical distance to the match engines, certain sites with a particular profitability time-ratio in play, and favorable speed/distance, and relational location or co-location, emerge as preferred temporal-informational network hubs.

Free market modeling assumptions and mechanisms appear to spatially implode or contract the time span and determine the spatial context in such everyone can know the exact price of a financial instrument. Thus, the new spatio-temporalities of rent extraction not only produce new economies of resource exploitation, but also concentrate power (Golumbia, 2013).

As algorithmic strategies reveal new ways in which geography, finance and technology interact, they represent the "accelerando" of the Anthropocene in-crisis – the ability of human ingenuity to create new pathways and capacities in its effort to shape society (for profit) and, by extension, transform the physical world. Yet as exciting as this techno-optimist vision may be, and as financially beneficial for certain types of firms, clients, and select regions and sites of prosperity within global cities, it is clearly, a spatial future that privileges the very few. In a zero-sum sense, HFT directs capital to profit-making activities that, often, have little connection to social development and environmental sustainability in real places. With respect to the environment, late finance capitalism has, admittedly, come to recognize that certain types of environmental management (even sustainable practices) can be rendered into centers of profit making. Whether their inclusion of sustainability, in some fashion, constitutes "green-washing" of the economy or an actual understanding of what is at stake at the planetary scale, may still be debatable. In the two case studies that follow, I will examine if and how algorithmic strategies represent a new era of environmental finance in the Anthropocene, and a new era of algorithmic capitalism in the financial-scene.

The spaces of timing and ways in which market information both alienates from and constitutes the great acceleration

While economic geography has been slow in recognizing the Nature-Society "complex, and acknowledged it as a "divide" (Bergmann, 2017), so has the representations of HFT and algorithmic economy. Even though many forms of ontological reductionism exist, "we cannot talk about the world of "nature" or "environment" without simultaneously revealing how space and time are being constituted within such processes" (Harvey, 1996, p. 263). Accordingly, algorithmic economies embody particular representations of time and space that become constitutive of the regulation of Earth-system and financial system interactions. Insofar as algorithmic economies mark a new era of environmental finance – the valuation of environmental change produced through new technologies – spatio-temporal-environmental figurations seem fundamental to the Anthropocene and the great acceleration (Steffen et al., 2015). Ergo, in its critical reading, the very definition of the Anthropocene-at-risk should include the agency and mechanisms of algorithmic economies with respect to the environmental-social externalities they precipitate.

While the Anthropocene debate intersects the heart of debunking the ontological and ideological implications of valuation (the act of finding the right prices for eco-system services' social-environmental consequences notwithstanding), I analyze algorithmic market information through a relational economic geography approach that draws on intersections between absolute, relative, and relational space. Such analysis would better contextualize algorithmic economies by taking into consideration non-human, Earth-systemic dynamics of the Anthropocene, hence opening up possibilities for different types of quantification associated with conceptions of space.

Example 1: The value of spatio-temporal market information - Nature decoupled?

Recall the earlier example of the broker that manages your pension. Imagine how data flow through the browser operator's servers, when algorithms trade shares on your behalf. Say they placed an order at USD20.01, and a microsecond later the market price drops to USD19.95. Imagine that an algorithm mops up your data, alongside thousands of other orders, in the process of compiling "a full picture" of all the bids and limit orders pending. This enables the algorithm to quickly buy at a lower price, sell to you, and appropriate the difference. Insofar as algorithms are able to act simultaneously as buyers and sellers within microseconds, spatio-temporal market information – the multiplicity of pricing in and between time and space – elide those phenomena that are not constitutive within such time frames. HFT simply converts valuation of social and material phenomena, say climate change operating at other temporalities, to series of microseconds. Yet they profit from them. Crises within milliseconds for instance have nothing to do with socio-ecologic processes operating at time-scales within decades, hundreds or thousands of years. In HFT these slower socio-ecological temporalities, are only valued if it concerns these timeframes.

Consequently, non-human techno-financial trading does not only accelerate market information, it reduces it to only a matter of affecting the immediate form of appearance of say, carbon dense assets. In socio-economic decision-making information is reduced to be relevant only within that particular timeframe, whereas other spatio-temporalities of occurrences are ignored.

As the big data harvesting and processing accelerations widen and market information flows accelerate, the socio-natural divide produced by HFT reductionism is constituted through spatio-temporal figurations, whether market information relates directly (e.g. carbon dense sector) or indirectly to natural resources and ecosystems or not. A great oil spill as that of the deep water horizon (2010), affected BP shares for month (accounting for the negative environmental externalities, replacement-ratio, fines and cleanup), while the new possibilities of fossil exploitation in the arctic, paradoxically caused by climate change, put pressure on the vulnerable environmental qualities, but are not accounted for.

Knox Hayes (2013) argues that markets divorce financial products from the material context they are supposed to represent. The “material-value divorce” intensifies, as changes in price in a microsecond do not represent changes in the value of the firm it represents, and yet, the constitution of market information relies on material practices. Instead algorithmic finance appropriates value out of other processes through the formation of spatio-temporal information inequalities in which its material context, conceptualized algorithmically, is reduced to the information necessary to exploit value within microseconds. By contrast geological processes span thousands, millions, and billions of years, implying that financial acceleration further alienates and divorces from the great acceleration (ecosystem service, such as carbon sinks operating at another temporality) widening the divergence between the Earth-System and financial system. The way in which nature is valuated in algorithmic capitalism is in an external and highly alienated form – since the valuation undermines natural processes operating at other temporalities. Harvey (1996) argues commodities are not only things but also processes and socio-natural relations. Their different spatio-temporalities – temporality of climate change and accelerating capitalism – are co-constitutive of one another.

Designed to accelerate the rate of capital turnover, financial markets constitute both divergence and convergence between the financial- and earth systems through further expansion and widening of spatio-temporalities (t/t) at financial markets and the spatio-temporalities (t/t) at which environmental systems operate. As Knox-Hayes (2013) argues, finance may undervalue the rate at which the earth system operates and reproduces itself. Algorithmic capitalism does not do that at all. To pin it down, the highest form of detachment from the nature-capital relationship is founded in the acceleration of financial capital while intensifying externalities to processes (for example, climate change) operating at other spatio-temporal scales. Thus, algorithms seem to speed-up the great acceleration that articulates finance capital, technological innovation, organizational complexity, and the consumption of nature – all four anthropic interventions upon the nature-society complex.

Algorithmic responses to natural disasters. When finance speeds up, will human-environmental interactions do the same?

Financialization, Knox-Hayes argues, creates distortions in the representation of financial value of nature and the application of that value to the management of environmental systems. "In particular, by removing value from its objective and spatial and temporal connotation, financialization introduces a disjuncture between the representation of value and the production of value by environmental processes… [T]hrough financialization they diminish environmental value" (Knox-Hayes, 2013, p. 118). In this section, I demonstrate that this is, indeed, the case, independent of spatio-temporal figurations. Nevertheless, algorithmic environments appear to confirm Knox-Hayes' (2013) conclusion, that the ability of markets to distort value and compress the space and time of production, threatens the material integrity of natural systems. I now turn to examine how algorithmic strategies perform peculiar forms of adaption to climate change by managing risk in ever-smaller time fractions. With respect to the Anthropocene-at-risk, I demonstrate that HFT algorithms contribute to worsening and deepening environmental crises (wildfire, drought or famine) by speculating on them while reducing (and redistributing) financial risks, not environmental.

As capitalism accelerates, market dynamics and the market's internal contradictions run ever faster. Consequently, we should expect to observe crashes and bubbles more frequently in a given time-scale ratio. According to the UK Foresight Project (2011), if financial capital is operated by HFT we have two temporalities working at different scales (t/t). "Imagine a movie in which you slow down frame by frame. Then, HFT slows down and becomes low frequency trading, such as daily trading. If the correspondence is 1 second of HFT corresponds to 1 day of low frequency trading in 1962, say, then one crash per year in 1962 would correspond to one crash every 4 minutes in HFT time!" (Sornette and Becke, 2011, p. 14). This is astonishing, and still the explanation is incomplete, because it neither takes into consideration interconnections between different temporalities at work on different markets, nor the relationships among technology, space, and the environment. What it essentially also implies is that the profit from financial capital represents another temporality than productive capital (working capital). Sornette's and Becke's (2011) conclusion, when related to the Anthropocene, that new 'crash algorithms' will likely be developed to trade during periods of market stresses in order to profit from these periods" (Sornette and Becke, 2011, p. 3) becomes especially meaningful.

Algorithms and the atmosphere - Technology, Space and the Environment

Relationships between HFT financilization and environmental change are complex and involve interconnections between absolute, relative and relational space.

Consider the case of spatio-temporal information equality as a spatially and structurally optimized infrastructure of cables, computers, and algorithms. Now conjure the financial micro- and macro-geographies that implicate the price-variances that emerge between the same shares traded at different stock exchanges: these would include 'absolute space,' in terms of the time it takes information to travel from point A to point B. 'Relative space,' defined in terms of the relative distance between, and the spatial configuration into a network, of actors (actor A is closer to the match engine than actor B, but actor B has faster technology or buys first access packages). 'Relational space' in terms of the price-locational and market information locationality (spatio-temporality of market information), relational to the traders, technology, shares traded, place and the firms they represent. Properly contextualized, such spatial representations of a network operating under HFT rules, can lock down a commodity or a region as connections to, and contributions from, many distant processes and places become determinative of its economic structure, function, sustainability, and social equity (or most likely inequity) profile.

By way of illustration, consider a large London-based broker intending to sell shares on different markets at the same time. By a few keystrokes they execute their order in Stockholm, Frankfurt, and London at the same time. Algorithms ride on large orders, because they often affect price. As HFT is faster than the time it takes to execute the large order, HFT market information travels faster to Stockholm than traditional electronic trading, so when the order hits Stockholm, the price has already changed. The space-locational strategies operate within absolute, relative and relational space simultaneously, which can be understood as denominated relativistic arbitrage (Buchanan, 2015). Since the location at which traders get the earliest possible information is located at the middle-point between two exchanges, Chicago and London would be in the middle of the Atlantic Ocean – a location that benefit from "spatio-temporal" price imbalances between the exchanges.

Example 2: Algorithmic responses to natural disasters

As algorithms are able to react to market news and structure trade between different markets simultaneously, in this section I examine if 'crash algorithms' harness (spatio-temporal) data of natural disasters, anthropogenic or not, and its possible consequences to the Anthropocene in accelerando. A future scenario is that algorithms also take into account natural disasters that, for example, affect the price of insurance companies' shares. It could be weather forecasts used to adjust for long-term risk reduction (typhoons, hurricanes, wild fires, flooding, landslides or draught and famines), seismographic data to forecast tsunamis and earthquakes (ultra-fast risk reduction), or volcanic eruption data. To my knowledge, there is no scholarly literature on the relationship among algorithms, HFT, and natural disasters.

In examining how algorithmic strategies construct responses to natural disasters I assessed HFT data from the 2011 tsunami event in Japan (March 11, 05:46 23.0s UTC), and the 2017 Hurricanes HARVEY, MARIA and IRMA in the US. Japan is subject to frequent earthquakes and is an economy heavily dependent on HFT trading (Hosaka 2014).

The Japan Exchange Group (JPX), including the Tokyo Stock Exchange, provided data within the first minute of the tsunami event at the Tokyo Stock Exchange (March 11, 05:46 23.0s UTC). The Japan Meteorological Agency (JMA) (Earthquake Early Warning System) estimates arrival times and initial movement of the first observed waves in coastal areas, and also provides information on the arrival times and scale of the highest waves observed as of the reporting time. HFT data at Tokyo Stock Exchange, however, show no algorithmic reaction to either the seismographic Earthquake Early Warning System, or the Major Tsunami Warning. The importance of HFT financialization with respect to environmental change, is not dependent on instantaneous reaction to an event. Rather, one should refrain from the ontological reductionism (the act of associating a number with an object). Environmental change configures as incommensurable, when e.g. climate change is sliced into microseconds, yet widening the divergence between the Earth-System and financial system.

An interview with a leading HFT expert at DTN Company, confirms that he is "not aware of trading systems designed specifically around seismographic events" (Interview A, 2018). A top representative from JPX, who wished to remain anonymous, confirms that no trading algorithms are currently designed around natural disasters. Yet, he says: "There is a case where the futures' price fluctuated simultaneously with the Earthquake Early Warning System. This is entirely just my own personal opinion; HFT algorithms use information on natural disasters for trading" (Interview B, 2018). While it is not found that HFT algorithms reacted in the minute after March 11, 05:46 23.0s UTC, HFT responded to human praxis (news and market decisions) as the Tsunami reached Japan.

The case of Hurricane Harvey is trickier, since the temporality of the catastrophe span from 22 to 29 August 2017. DTN Company informed they are unaware of algorithms designed around hurricanes and other natural disasters, but that algorithms trade on them. The difference is that algorithms designed around natural disasters trade on market information directly linked to the event, whereas ordinary algorithms trade on human reactions to that event (news reports etc.). Insofar as no crash algorithms deploy within microseconds following environmental catastrophes, algorithms take into account human responses to such events, in ways that increase risk to some and reduce it to others. By way of illustration, relational crash algorithms are a means of economic risk management to the brokerage firms, and solely the brokerage firm. Risk reduction in absolute space (in the "real world," if you like) is a matter of obtaining "data on natural disasters" before the competitors, consequently pass on market risks to others in case of a catastrophe. Moreover, in relative and relational space (depending on the spatio-temporality of the natural disaster - earthquake or drought) the location of… to the epicenter of a catastrophe, to the areas affected, industries, sectors, and relative to other market actors, affects risk management. The longer the distance from the epicenter, the longer the reaction time, hence the ability to transfer (not reduce) economic risk to others. In consequence, HFT algorithms does not only transfer risk to other investors, but also to people and places around the world.

Thus, relational crash algorithms produce relational economic geographies transferring market crises from one geographic spot to another at the temporality of HFT time, and at other spatio-temporal scales, they affect the geography of difference. As algorithms speed up, so do human environmental interactions.

Add to this the social and human cost of natural disasters. By way of illustration, Wainwright and Mann (2012) analyzed the 2010 wildfires in Russia. The fires blazed and grain prices doubled. This, in turn, made the poor even poorer and produced a famine in many third world countries (Wainwright and Mann, 2013, p. 3). Algorithms can be profitable, but not productive – they produce no value. Rather, algorithms re-allocate exchange value. Technologies like HFT can therefore produce crises by creating instruments to monitor exchange value, – not by valuating ecosystem services, but environmental risk. Accordingly, when algorithms speculate on natural disasters this will make them corrosive of society and environment, even if they would support profit-taking in the short term for a limited group of firms and investor clients. Algorithmic capitalism produces extraordinary unevenness to the world's at-risk population while it is a peculiar form of adaption to climate change, whether directly linked to weather forecasts or not. Haraway (2015) finds the Antropocene is about the destruction of places and times of refuge for people and other critters, say irreversible processes. Algorithms might serve just that.

In closing, HFT is axiomatically not mindful of earth system resilience and sustainability as it is entirely profit-focused. HFT is an early, primitive form of AI without the philosophical, ethical constraints that would make it mindful of the consequences of accelerated trading. HFT is a late-age mechanic process that, by virtue of its increasing prevalence in, and capacity to shape, financial markets, has an ever-increasing impact upon nature and society. Devoid of social or ethical compass, it is computer code in the service of finance capital. It lacks social or environmental mindfulness, as its inventors and users themselves, as agents of the "Capitalocene" (as much as the Anthropocene) are not mindful of the impacts of HFT profit-taking upon environmentally fragile places, regions, and communities. There is not much algorithmic match making akin to paraphrase Haraway. Rather the Capitalocene, e.g. in the Paris Accord, urges market-driven mechanism (CDM, NDC) to govern the political ecologies of the productive capital, not finance. One way to make a more akin algorithmic economy would be to let the Paris Accord adopt finance and direct future investments, e.g. with a carbon/Tobin tax. Algorithms seem well prepared to monitor that.

Conclusion

The multiple aspects and capacities of HFT offer important insights into the acceleration and expansion of the world economy. HFT defines new spatio-temporalities and reveals that algorithmic economies reshape the Anthropocene in a manner that accent social inequality and environmental degradation. Algorithms both diminish environmental value in minor fractions and constitute environmental value through peculiar forms of adaption to climate change.

The techno-optimist accelerando of financialization in scale and time (outwards as well as inwards) simultaneously accelerates the capital-intensive exploitation of the physical environment. Algorithms spatially and temporally expand the benchmarks under which the environment (processes or resources) is considered to be profitable. By extension algorithms, such as those supporting HFT, define and justify material practices that are valued as profitable in a given time-scale ratio. Designed to accelerate the rate of capital turnover, financial markets constitute both divergence and convergence through further expansion and widening of spatio-temporalities (t/t) at financial markets and the spatio-temporaltities (t/t) at which environmental systems operate. The acceleration of capital seems to accelerate human-environment interactions while it restructures its production of uneven development.

Algorithms do not value the environment unless it produces risk relevant to HFT temporalities. Further, it produces divergence from the environment and increasingly alienates the logics of financialization from the maintenance of long-term sustainable earth system dynamics – the rate at which ecosystem services operate and reproduce themselves. The highest form of detachment from the nature-capital relationship is founded in the acceleration of financial capital as it is intensifying and producing new externalities to natural processes (such as worsening the impacts of natural disasters and climate change). Thus, algorithms seem to speed up the great acceleration of economy and society in the Anthropocene of the 21st century, by ways in which they further distort environmental value that threatens the material integrity of natural systems.

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