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Money's eyes: the visual preparation of financial markets

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Money's eyes: the visual preparation of financial markets

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Abstract

Participants in today's financial markets confront a sea of data. While the availability of market data has benefits it also creates problems, notably those relating to questions of meaning, judgement and intervention: how to make sense of these flows – how to see the 'market', its futures, and thus act pre-emptively. Over more recent years financial organizations have been turning to new technologies of representation, in particular the design and application of visualization software in an effort to enable better visual imagination of and interaction with markets as they unfold in real time. 'What you see is what you risk' in many respects captures the thinking or at least the desire underlying the employment of the latest visualization software. The more powerful one's vision the better able one is to participate in increasingly complex financial markets, at least in theory.

Based on recent interviews with those involved in developing and using the latest visualization software within some of the key markets of global finance, and developing the influential work of Daniel Beunza and David Stark, and Karin Knorr Cetina, in particular, this paper adopts a cultural-economy-of-finance perspective to examine the implications of these new techniques of representation. The paper argues that the latest visual turn within finance should be afforded a more central position in the study of contemporary financial market practices.

Keywords: visualization; visualization software; market devices; risk; financial market practices; cultural economy.

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Introduction

The organs of global finance rely upon and face a continual stream of numbers. These data range from official figures published by the likes of the Federal Reserve and the IMF, real-time market data from market exchanges such as Chicago Board of Trade, to news and market reports supplied by 'secondary economy' suppliers such as Reuters and Bloomberg, as well as, of course, proprietary data generated by financial organizations themselves. While the growing availability of market data has benefits it also creates problems, most especially those relating to questions of meaning, judgement and intervention: how do financial agents make sense of these flows – how do they see the 'market', its futures, and thus act pre-emptively? One solution to this cluster of problems is said to reside in the development of new technologies of representation, in particular, the design and application of visualization software. Such software is being introduced to enable better visual imagination of and interaction with markets and the data generating market activity. This is not a case of visualizing new data but centres instead on trying to understand existing data in other dimensions. The software in other words equips the agents of global finance to better track and act in relation to the seemingly abstract movements of modern financial markets. As this suggests, visualization software has joined the already large array of software that 'mediates, saturates and sustains' contemporary financial markets, to borrow Stephen Graham's (2005, p. 562) phrase.

Based on recent face-to-face interviews[1] with those involved in developing and using the latest visualization software in London and New York and within some of the key global finance markets, such as US Treasuries and global equities, this paper adopts a cultural economy of finance (Amin & Thrift, 2004; Pryke & du Gay, 2007) perspective to examine the implications of these new techniques of representation and suggests how visualization techniques empower modern finance with fresh eyes designed to interpret and manipulate data, 'to see more and understand faster'. By drawing on these interviews and the work of economic sociologists and others, the paper contributes to the growing literature on finance, in particular where the organizational practices and knowledge formation that enable finance to flow are the focus. Specifically, the paper argues that critical engagement with the techniques used to visualize financial flows should become central to the broader drive to understand more fully the role of 'market devices' (Callon *et al.*, 2007) utilized by financial agents, where devices stand to 'reconfigure' the markets into which they are introduced and thus potentially the spatial outcomes produced through market practices formed around them.[2]

While some devices are central to the generation of the rising flows of data that stream into financial organizations, others, such as those discussed later in the paper, are key to making market data visually more digestible. Put another way, 'learning [how to] do *global* finance' (Clark & Thrift, 2005, p. 245, emphasis in original) nowadays is about learning how to re-visualize markets – 'seeing the

interrelationships between the parameters that drive markets and prices' as one investment bank representative expressed it (interview). This desire to re-visualize market action is not however uniform: there will be differences between markets (simply because not all financial markets and their characteristics are the same), among organizations, and teams within these organizations, even if differences vary only slightly. The abundance of data might seem like good news for those involved – input into models, market positions ... all may be made that much crisper and less risky as a result, at least in theory – but the full story is not that straightforward, as this paper suggests. Why this is so can be better appreciated after a quick rehearsal of five recent trends in key financial markets, each of which also serves to point to the growing interest in techniques of financial market visualization.

The first complicating factor is woven into the meteoric rise in the availability of data. New ways to 'mine data', both those publically available, such as price of shares on the FTSE 100, and proprietary data generated by individual investment banks, must thus be looked for. The way to make profits today is to innovate, not to add more data streams (Beunza & Stark, 2004) and do the same old thing but ten times faster. As Beunza and Stark put it, with the excess of data the central question becomes 'how do you recognise an opportunity that your competitors have not already identified?' (2005, p. 85). The second development is closely linked and is the move to screen-based trading. The question for market participants becomes how to 'get a feel' for markets – understanding trends, judging liquidity and market depth, say – when a sudden surge of market activity is simply represented as a board of shifting and flashing prices on the screens in front them.

Third is the entanglement of risk profiles. As the recent subprime crisis and its aftermath highlight, less than straightforward mathematical-financial techniques are used increasingly to transform the risk profile of one financial instrument into the basis for the innovative development of other instruments, thus making it more and more difficult to judge just where risks lie and the unknown potential for some new products (such as structured credit products) to amplify risks as well as supposedly distribute them relatively safely – in a pre-crisis world – among market participants (see IMF, 2006).[3] At the organizational level, where financial management has become an 'organized bureaucratic process' (Clark, 2005, p. 105), judging these risks, their spatialities and temporalities, is a growing concern (Clark &Thrift, 2005). To track the risk position of individual traders and of overall market developments is thus crucial, and this is a task that cannot be left solely to trading software. As one investment bank representative commented, even with the move to algorithmic trading where the capabilities of market-makers are supposedly encapsulated in the software, not everything is in fact captured: trends may emerge that human traders will have to figure out and new devices such as visualization software are called for to help figure out 'what's going on'.

This trend is very much linked to a fourth, to what Michael Power (2007, p. 3) has referred to as the rise of risk 'talk' and the expansion of risk

management ideas since the mid-1990s, not least within financial organizations. Such organizations have been fast to invest further in what Power terms a 'new reflexivity of organizations and organizing around risk management'. The materials designed and used to help visualize risks – the software, the screens and so on – help shape the 'practices organized for the explicit purpose of representing and handling risk' (ibid., p. 4). They are used to help build a visually enhanced knowledge of financial risk.[4]

The fifth issue, as intimated above, arises from the mathematical complexity of many new financial instruments. Number is not everything; mathematical expressions and financial interpretations of the variety of hazards such as credit risk within financial markets and specific market characteristics such as volatility 'skews' and 'smiles', for instance, more and more need to be made visible (interviews). Importantly, and with a slight touch of irony it seems that even the quants (the name given to those specializing in the techniques of quantitative finance) now require the qualitative to make sense of the quantitative and to be able to communicate their solutions to others; they wish to turn the 'numbers into pictures'.

The collective response to these trends and the issues they raise has led, as this suggests, to experimentation with ways to empower financial market participants with new eyes. It is an examination of these various visualization techniques that forms the core of this paper.[5] The next section briefly reviews what is felt to be the most influential work on the visual and financial markets in order to conceptually locate the rise of visualization software within financial markets. The third section considers how the centrality of forms of visualization that enable interaction and manipulation may be influencing how financial market knowledge is now produced. By way of a discussion of current examples of visualization software and their associated techniques, three shorter sections (the fourth, fifth and sixth sections) critically explore and develop the conceptual influences discussed thus far. The conclusion considers what the introduction of software that gives finance its latest calculative eyes might mean for how contemporary financial 'markets' are understood, how risks are understood within markets and organizations, and what the wider, 'worldly', effects of such techniques in the preparation and performing of financial markets might entail.

Approaching finance, markets and the visual

The turn to the analysis of finance by those working within, for example, the social studies of finance, economic sociology, social anthropology and geography has been noticeable in recent years.[6] Much of this work has tended to leave largely untouched the visual box of tricks that lies at the centre of the key markets of modern finance. There are of course notable exceptions. The work of Karin Knorr Cetina (2003), including in her collaboration with Urs Bruegger (2000, 2002a, 2002b, 2002c), and of Daniel Buenza and David Stark

(2004),[7] together with recent intriguing work by Caitlin Zaloom (2003, 2006), provides rare moments where inquiries into the workings of financial markets have not just recognized the presence of props to aid the visualization of markets – the rise of 'screen-based' rather than so-called 'open outcry' floor-based trading – but have placed these technical artefacts[8] at the centre of the analysis. The importance of this work warrants an extended review as this helps to locate the discussion of the latest visualization software which absorbs the remainder of the paper.

In their work on the organization of trading floors in Wall Street, Beunza and Stark (2004) demonstrate the various ways in which daily traders deal with a core problem – 'how to recognize an opportunity' in the markets. Although they encountered a 'world abundant in information, with dazzling, dizzying speed' they recognized that strategic advantage in the derivatives markets they were studying lay not in economies of information and having the right mathematical formula (see MacKenzie & Millo, 2004) but in the 'socio-cognitive process of interpretation' (Buenza & Stark, 2004, p. 372). They noticed that the financial organization they were studying purposefully organized the trading floor to facilitate such interpretation. The careful production of the space of the trading floor aims to aid profitable innovation through collaboration among the hybrid collective gathered to make sense of market movements and to move these markets. As they explain in relation to the market they were studying:

> The cognitive challenge facing our arbitrage traders – a challenge central to the process of innovation – is the problem of recognition. On the one hand, they must be adept at *pattern recognition* (matching data to models, etc.). But if they only recognize patterns familiar within their existing categories, they would not be innovative (Clippinger, 1999). Innovation requires another cognitive process that we think of as *re-cognition* (making unanticipated associations, re-conceptualizing the situation, breaking out of lock-in). It involves a distinctive type of search ... where you do not know what you are looking for but will recognize it when you find it.
>
> The organization of the trading room ... is equipped (quite literally) to meet this twin challenge of exploiting knowledge (pattern recognition) while simultaneously exploring for new knowledge (practices of re-cognition). Each desk (merger, arbitrage, index arbitrage, etc.) is organized around a distinctive evaluative principle and its corresponding cognitive frames, metrics, 'optics', and other specialized instrumentation for pattern recognition. That is, the trading room is the site of diverse, indeed rivalrous, principles of valuation. And it is the interaction across this heterogeneity that generates innovation.
>
> (Buenza & Stark, 2004, p. 373, emphasis in original)

Arbitrageurs seek qualities, the 'categorical attributes' of, for example, a company, rather than seeing an asset or stock in purely quantitative terms; they deal in 'abstract qualities' (Buenza & Stark, 2004, pp. 376–7); they

work with ambiguities – belief and doubt (see Miyazaki 2007). Financial engineering in this sense is not wholly focused on welding together supposedly dependable data; it requires forms of what might be termed techno-sociation – the careful, quite often experimental, blending of humans and 'market devices' (Muniesa *et al.* 2007) – within purposefully designed financial spaces: spaces, that is, in which technical artefacts, such as screens and software, and human traders together weave effective calculative agencies. In such spaces, the screen world does not dominate (as is suggested by Knorr Cetina and Bruegger [2002b] in their study of foreign exchange, quite a different 'global financial market'); here atmosphere is highlighted, cognition is distributed through the room across what the Beunza and Stark call 'socio-technical networks of tangible tools' (2004, p. 378). As Nigel Thrift, Manuel Castells and Saskia Sassen have argued, the greater the flows, the more need there is for places where financial actors can get together to talk through market developments. Within financial organizations, the conversations do not flag; technical artefacts keep things moving – they are integral to how the markets think and see. Beunza and Stark put it bluntly: 'without instruments for visualizing properties of the market, they [the arbitrageurs] could not see opportunities ... No tools, no trade' (2004, p. 389). These authors found that the traders' Bloomberg workstations and customized screens were crucial instruments or tools.

> These dramatic, extra-wide, high contrast Bloomberg flat-panel monitors serve as their workbench. Bloomberg terminals include a specialized monitor, color-coded keyboard and a direct intranet cable connection to Bloomberg LP. Even more expensive than the physical terminals is the software that comes with them, structured around five areas that include data (price, volume, etc.), analytics for parsing and visualizing the data, news (from 1000 journals around the world), trading support, and information on trade execution ... Screen instruments are not mere transporters of data, but select, modify and present data in ways that shape what the trader sees.
>
> (Beunza & Stark, 2004, p. 390)

The 'best trading rooms', as Beunza and Stark note, are those that 'bring together heterogeneous value networks for creative combination' (2004, p. 393). Multiple time-spaces are fed into trading places, reworked through software to appear on screens in a variety of forms – such as graphs, tables or coloured squares – to enhance and transform data codes into, say, investment opportunities that can be cognized visually. The arbitrage traders are 'actively experimenting to uncover properties of the economy'; 'the new instruments of quantitative finance – connectivity, equations and computing – visualize, cut, probe and dissect ephemeral properties in the project of interpreting markets' (ibid.). As Nigel Thrift has argued, calculation is no longer precise: 'making qualitative judgements and working with ambiguity' is central to a 'new form of seeing, one which tracks and can cope with uncertainty in way previously unknown' (2004b, p. 584).

Knorr Cetina (2003) and Knorr Cetina and Bruegger (2002a, 2002b) locate their discussion of screens within what they refer to as the 'flow architecture' of contemporary finance in which participants and the market itself have become disembedded. In addition to being best described as 'microstructured' (rather than simply network/relationally structured, as Knorr Cetina (2003) points out), flow architectures are dependent on 'global "scopic" systems' to make sense of the 'numerical flux'. These regimes both project market realities and bundle markets along in the flow. Surfaces such as screens, Knorr Cetina argues, reflect and project; the 'coordination and activities respond to the projected reality to which [market] participants become orientated. The system acts as a centering and mediating device through which things pass and from which they flow forward' (Knorr Cetina, 2003, p. 8). What is needed then to understand this architecture of flows are temporal concepts rather than, as she says, the social relational thinking of networks that arguably fails to capture what, for her, are the 'more reflexive temporal forms of coordination' that best describe financial markets such as FOREX (an inter-dealer rather than an exchange-based market) where screens dominate to 'display the market' and to 'conduct' trading (2003, p. 8). In making markets, the human traders and the screens 'melt together'. For Knorr Cetina the focus of attention is what she terms a 'global reflex system', a concept she introduces to capture the 'constellation of technical, visual, and behavioural components packaged together on financial screens that deliver to participants a global world in which they can participate on a common platform, that of their shared computer screens' (2003, p. 8).

For Knorr Cetina (2003, p. 11):

> the terminals deliver the reality of financial markets – the referential whole to which 'being in the market' refers, the ground on which the traders step as they make their moves, the world which they literally share through their shared technologies and systems. The thickly layered screens laid out in front of traders provide the core of the market and most of the context.

The layers are formed by prices, trading conversations, market stories, and news headlines and so on.

> It is this delivery of a world assembled and drawn together in ways that make sense and allow navigation and accounting which suggest the globally reflexive character of this from of coordination – and the scopic nature of traders' screens.
>
> (Knorr Cetina, 2003, p. 11)

A similar emphasis is to be found in Caitlin Zaloom's work. What she noted in her study of futures traders in London and Chicago is how the software had been designed to provide the simplest visual cues ('bold faced numbers in rectangular boxes') to 'represent market action': 'numerical representation shapes the traders' informational environment by elevating numbers to the status of the market itself'. The software aims to flush out all hidden

information and display it on the screen; by design, the numbers are meant to draw 'traders toward the market ... the market is represented in numbers' (2003, pp. 264–5). Yet, despite the effect of the work of the software designers to 'aesthetically rationalize the trading screen', which would in effect turn traders into 'observers' (2003, p. 176), the traders themselves, she remarks, 'do not passively consume the representations of the market that the screens provide'; they 'seek out nonquantitive information that is located within the market numbers' (2003, p. 269).

Knorr Cetina's observation of FOREX dealers would seem to share this interpretation: the system is reflexive and performative: 'it affords the possibility of performing the market transactions and other interactions through its technological and software capabilities' (Knorr Cetina, 2003, p. 11). The reality of the screen contains the trader's lifeworld (Knorr Cetina & Bruegger, 2002c).

Knorr Cetina talks of the 'mirrored market' 'that is comprehensively projected on computer screens' and which 'acquires a presence and profile of its own, with its own temporal and other properties'. What this means is that traders are 'not simply confronted with a medium of communication through which bilateral transactions are conducted ... They are confronted with a market that has become a "life form" in its own right, a "greater being" ... a being that is sometimes coherent but at other times dispersed and fragmented' (2003, p. 12). And as more than prices pass through the architecture of flows (rather than the network of trades), screens have in an important sense 'enlarged the world' (ibid.) of FOREX. In the process the screen has thus become 'a building site on which a whole economic and epistemological world is erected': price histories, the best prices for currencies worldwide, custom-made calculating techniques ... feed this screen world. Screens then are not mere '"mediums" for the transmission of pre-reflexive interactions' (2003, p. 13; see also Knorr Cetina & Bruegger, 2002b); they are the way the world is known.

As this brief review of recent research highlights, visual tools such as screens herald changing practices of calculation within key financial markets. Yet the application of the latest visualization software does not just represent existing market activity, mainly in the form of number, however; the software uses these numbers to generate 'new' visions of the space-times of financial markets. The software in many cases enables the visualization of overlooked or even undetectable market characteristics lost in previous representations of market action. Significantly this is active rather passive representation in the sense that the visualization is achieved through software that allows the interrogation and manipulation of the 'pictures' generated by financial number and market movement.[9] In this sense, the visualization software brings markets, or perhaps more correctly critical components of markets (such as the so-called volatility smile central to options pricing or key spreads central to the Treasuries markets), into full being and, in so doing, these technological artefacts stand to alter the formation of financial knowledge, in terms of both its geography and its potential consequences.

Visualization: 'what you see is what you risk'[10]

The reduction of everything to number certainly aids the performance of calculation, yet fulfilment of the calculative promise calls for the re-presentation of number to facilitate more qualitative techniques often associated with markets, such as judgement, evaluation, review and observation. The growing emphasis on visualization software[11] (in all its broad interpretations) is a market-based recognition of the sensual side to the performance of financial economics and the need to do more than capture information; there is a requirement to turn information flows into knowledge about the markets. And this is achieved through practices such as visualization that collectively 'probe and dissect ephemeral properties in the project of interpreting markets' (Beunza & Stark, 2005, p. 95).

The shift from spreadsheets to 3D visualization of data, the use of screen space to visualize the temporalities of the markets and so on is more than a simple move up the IT chain. As the previous section argued, such a technological development is arguably a 'transformative' shift in the way the world is presented and becomes known to financial market participants. As Peter Taylor has recently remarked:

> Visualization is much more than image creation; data are not just passively displayed, they are depicted in such a way as to generate new knowledge. In visualization the image is not the final output; the viewer interacts with it to find new patterns and relations in the data. It is this feature that makes visualization potentially so important: to go beyond display and invite people to think in new ways about their world.
>
> (Taylor, 2004, p. 120)

Moreover, it might be said that the digital formation pieced together around the latest visualization techniques is 'constitutive' of 'new social domains of action' (Lathan & Sassen, 2005, p. 3; see also Sassen 2002, 2004). This then raises not just an issue about how the visualization of financial data helps to constitute financial knowledge of the world (Zaloom, 2003, p. 269) but more speculatively – and to suggest a question the answer to which is beyond the scope of this paper – how knowledge in large part produced visually shapes the relationship between these markets and the world. As Thompson remarks, graphs, figures, even tables should not be seen as

> primarily 'representational' in the sense of their ability to communicate something, but rather as primarily significatory. They always signify but need not necessarily represent (something else). This is an important distinction. It enables us to approach visualisation (in its multifarious forms) as *constitutive of a reality rather than as a mere reflection of it* (however accurate or distorted). And this pertains to all forms of visualisation. Thus from this perspective intelligibility, knowledge or sense are the effects of the form of visualisation ... not the conditions of their possibility or existence.
>
> (Thompson, 1998, p. 286, emphasis added)

Thompson takes this further (1998, pp. 286–7) in arguing alongside Ian Hacking that visual techniques are 'interventionary' as well as significatory. Being both significatory and interventionary, visual techniques may alter the 'contours and trajectories' of knowledge formation which holds implications, it is contended, for the making of financial knowledge through visualization software. 'Visual aids give you a different dynamic – instead of looking at just the amount on offer, you get a feel for what's going on, whether it's one guy or a lot of smaller offers', as one US Treasury trader reported to the *Financial Times* (Hughes & Baxter, 2005; see also 'Visualizing US Treasuries' section below). Similarly, the spaces of potential strategies open up to organizations, such as hedge funds, facing increasing competition to find new funding opportunities. As the quote opening this section highlights, nowadays the emphasis is 'What you *see* is what you risk'. As the quote continues, and as my interviews support: 'Seeing what is happening in the business is the cornerstone of good execution [decisions to buy or sell] ... Today, financial institutions are looking beyond tabular, grid-based views of their business data – views to easily spot trends, see anomalies, or connect different data contexts' (*Wilmott*, 2006, pp. 14, 16). Put differently, the capabilities contained within visualization software include the potential for faster means to view data in innovative ways, to spot trends and acquire 'actionable insight' (interviews).

The application of visualization techniques discussed later in the paper (all but one of which was designed originally for use in areas away from finance, such as medical research and geology) enables the financial economics and market components to be seen in a range of colours and shapes; outcomes of 'economic' action have shape and colour which aid the progress of markets. What seems to be a growing commonplace within financial markets, from global equities to US Treasuries, is a desire to play with the market and its constituent parts. Market developments may be slowed to enable a review of price formation and movements or to divert certain data into other more digestible forms of representation. For instance, fifteen-minute snapshots of a market's development can be recorded and then replayed by running them together to review trades and see which sectors and stocks performed best during the day. Using colours and shapes, rather than endless rows and columns of data, one type of software enables, for instance, a head of equity trading to look back on a day's trading to see where the best and worst trades were and who made them. Moreover, it is possible to play with the replay – to show trades every minute or every ten minutes, say. Such techniques to enable the re-visualization of market data established against chosen in-house criteria could be employed by an investment bank, for example, to help make sense of entangled trades and instruments where equity trading may be linked through derivatives to other stocks, interest rates and currencies.

Similarly there is a growing awareness of the usefulness of seeing the multidimensionality of markets in order fully to evaluate the interrelationships among variables (such as price, market volatility, profit and volume of transactions) so as to judge how the variables interact and thus to spot trends

and make better decisions. Achieving this through visualization techniques stems in part from the general agreement that images are supposedly better at communicating such relationships to the viewer; images help the viewer to improve their understanding of the interactions, hence the earlier emphasis on 'pattern recognition'. The argument runs:

> Using color, size, shape, and animation, visualization tools condense dozens of market screens, databases and financial reports allowing users to process information more effectively. Normal correlations become familiar to traders and analysts, through abnormalities in pattern and color they can discover opportunities.
>
> (Higgins, 1998; see also Panopticon, 2005; Tufte, 1990)

The new ways to visualize the markets and their movement actually give an added sensual depth to the way markets have been talked about. For instance it is now possible to see 'market depth' (see 'Visualizing US Treasuries'); the metaphor takes on an added dimension.[12] As a representative from a leading US broking firm active in the development of financial data visualization put it: 'Visual cues can give you additional information you wouldn't necessarily get from numbers' (Hughes & Baxter, 2005). Such developments seem to go hand in hand with the ethereal qualities associated with finance (see Zaloom, 2003, 2006). The more abstract and interconnected are the movements in price and risk, the less able are the 'old fashioned' means of dealing with numbers, such as spreadsheets, to cope with the requirements of agents dealing, strategizing, reacting ... in real time. The growing pace and abstract nature of financial data and the interconnectivity of financial instruments require economic agents to employ the senses in different combinations. The visual sense seems to be being brought to the fore in analysing financial market change and seeing more clearly the economics of finance (the mathematical expressions, the components and formation of market prices, etc.) and their implications, so much so that it is tempting to say that the technical enhancement of the visual sense is today central to the creation of meaningful market worlds among the hectares of fast-moving numbers.

Yet this is not simply to insist that the 'screen is now the market', as Knorr Cetina has suggested in the context of FOREX markets, for example, in the sense that all market-related information – where such information is the 'materiality of the screen world' (Knorr Cetina & Bruegger, 2000, 2002c) – and actionable insight are in some markets, such as FOREX, framed exclusively by the screen. Nor is it solely to do with the 'flow market';[13] the way, that is, the screen offers a reality which is '*processual in the sense of an infinite succession of non-identical matter projecting itself forward as changing screen*' (Knorr Cetina, 2003, p. 16, emphasis in original). For what seems to be common to all the software is that its design and implementation seeks not simply to re-present the market, to settle abstract signs within the screen and thus to bring them within reach, as it were; *interaction* with the screen[14] and thus the market seems to be a central objective: 'Moving the market around' (on screen)

(see 'Visualizing US Treasuries' below), 'drilling through' a market's components (see 'It's all about market watching' below), changing the viewpoint (see 'Enter "the quants" . . . ' and 'Visualizing US Treasuries'). Comments such as these, relating to the design and use of the software, reflect the reported pressing need to refine aspects of a market visually, to steady a market's movements as it evolves. The representations are re-represented, manipulated and then meaningfully engaged. Tracking financial market developments and making market judgements foregrounds the visual, the qualitative, rather than being left solely to the quantitative approaches favoured in key markets in recent years. Yet to appreciate the turn to the qualitative there is a need to rehearse briefly the arrival of the quantitative approaches to key financial markets. For it is even among these diehard number-engineers that the latest data visualization techniques are proving attractive.

Enter 'the quants' . . .

New techniques and established market practices tend to mix like oil and water. The microworlds of financial markets are equally averse to change; market cultures die hard and cultural skirmishes can turn into full-blown wars. Nevertheless, in recent decades alternative technological techniques for trading and discovering market possibilities have emerged within a number of markets central to contemporary finance, such as equities and foreign exchange where screens and electronic platforms to execute trades are now commonplace. Screens and electronic platforms, and the manner in which they have been adopted by human traders and integrated into the practices of market calculation, are not isolated illustrations of how a financial culture can be encouraged to shed old techniques and to regroup around some new technical artefact. The influential rise of so-called quants and the associated growth of quantitative finance are perhaps less obvious examples of the emergence of a sociocultural-technical practice that arguably has led to dramatic change within key financial markets. The entrance of the quants began in the 1970s and gathered pace from the 1980s onwards (see Das, 2006, p. 183; MacKenzie, 2006, pp. 136–7). First introduced into the large US investment banks such as Goldman Sachs and the recently departed Salomon Brothers, the 'rocket scientists', a tag that stuck to the new entrants with PhDs in physics and maths, applied their skills to finance to produce new jargon to describe hybrid instruments and soon made themselves indispensable to key financial markets (Das, 2006, p. 1867).

Quantitative techniques offer sophisticated, mathematically-based ways to play with numbers to produce, among other things, new financial products. Yet the wish to play with the numbers is not something that is exclusive to the quants. Traders and financial product designers for example need to be able to relate to the 'numerical flux', the cubes of data. This type of judgement is, as

Caitlin Zaloom notes, 'far from strict calculation' (2003, p. 258), as the following example illustrates.

. . . re-enter the qualitative: the need to see the 'maths'

As one visualization developer acknowledged, financial market agents already have their own visualization systems, systems they are used to and with which they have trained themselves to interpret data. The successful introduction of new ways of seeing hinges on being able to demonstrate how the new software enables market participants to see things – the emergent 'shapes' and 'patterns' – that previously they could not spot, particularly in relation to the *interaction* of market variables and in helping to understand the *correlations* among them, and their effects. This is relevant in derivatives markets in which the financial instruments (be they fixed income, interest rate and so on) are dynamically hedged, as a representative from one investment bank pointed out. Due to the costs of re-hedging, for example, market participants will benefit from knowing not just 'what is going on' (where the jumps in volatility might be, for instance) but also 'what has gone on'. This is particularly the case with large portfolios of such instruments where the impact of changing market conditions may be considerable. Here, what an investment bank might do (at a head-of-desk level, for example, rather than at the level of individual traders)[15] is to use visualization techniques to scan previous market environments in an attempt to judge possible future outcomes from past market action. Although not the quick-fix solution to all problems facing financial agents, the techniques that enable the future to be visualized based on past data patterns supposedly allow better decisions to be made on the basis of fuller information (interview) – 'better' in the sense that, by mixing in-house, proprietary, data and generally available data feeds,[16] visualization techniques help to explore shapes among the data that are persistent. The semi-stationary, data-as-pattern may then be questioned: 'What is this shape?', 'What's generating this?' This 'initial spotting' then allows action to be taken among the numbers in more informed ways.

In a similar fashion, the example below focuses on the desire to see the numbers, to 'represent the abstractions' (Zaloom, 2003, 2006) of quantitative finance, and centres on the performance of the Black-Scholes option pricing model[17] (Walton, 2004a, 2004b, 2004c).[18] The Black-Scholes model produces values for option volatility as a function of underlying maturity of the swap and the expiry time of the option. The relationships that are of interest are between volatility, maturity and expiry (the latter two being independent variables). However, seeing the solution is not straightforward; the value of a derivative may be discontinuous (for example, where there are discrete dividends). That is, the value of the option goes down, vertically, at such moments when the dividend is paid. What is important to the quants and others is to be able to see such discontinuities.

Seeing the solution is of interest not just to the quants but also to the financial product managers in charge of design, packaging and selling financial instruments. Visualizing the solution helps show how it might be shaped in a way that will allow the innovation to be sold. The characteristics of a new product can thus be talked through (often using a large conference screen) and related to a variety of possible market conditions. If, say, the discontinuities, in effect the temporality of the instrument, are not shown adequately, then the 'interesting things' that happen at the low end of the expiry time (where closer analysis may thus be beneficial) are missed. With fierce competition for market share and the accompanying higher margins and boost to a financial organization's reputation that comes with the successful financial innovation, the 'quants', the derivatives traders and the product managers need to be able to be sure of what they are seeing as they swiftly group around the visualization of data.

Significantly the emphasis is placed on seeing correctly, which is linked in turn to trading profitably: trading at the top/bottom of the ridge is the best place/time to trade, for example. Financial practitioners are thus interested in the qualitative shape; they seek to 're-cognize' features in the surface. There is a similar desire to see the relationships between key data, ideally to re-visualize the interrelationship between three variables – maturity, strike and price. Practitioners are interested in engaging with the irregularities, the spacing, among the components of the solution and to be able to do so by seeing them as shapes, to interact with them, in ways that make for more visually digestible analysis (Figure 1).

By viewing slices of data in this way, the argument runs, it is possible to reveal the characteristics of the surfaces and the all important 'volatility smile'.[19] The shape of the smile aids better judgement of, in this case, the relationship between strike values and the expiry time. Again the idea is for market participants to be able to interact with the data, to explore the implications of the 'folds', for instance, and the interrelationships between, for

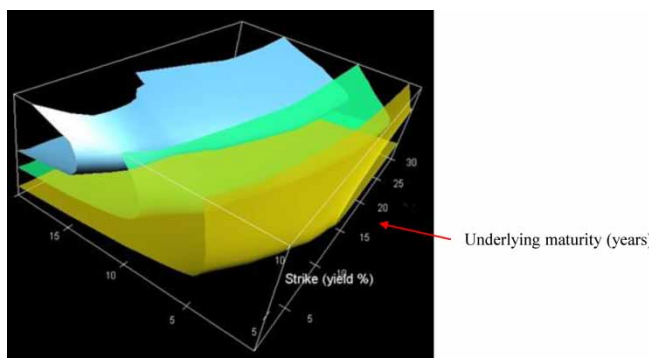


Figure 1 Multiple volatility surfaces: surfaces for volatility = 10, 12, 17 per cent (full-colour version available online)

instance, volatility and the strike value. Those viewing the visualization can then ask 'Is this is what we should be seeing?', 'Should the volatility be changing in this way as we move through the data?' (interviews). The ability to see and interact with the numbers arguably helps too in the preparation of a market for a new instrument (and how it is marketed and sold).

The process of generating the visualization has thus been an important part of financial innovation, both in designing and selling new 'products'; financial innovators or 'bricoleurs' (Engelen *et al.*, 2009), perhaps buoyed by such techniques of seeing, have happily created what they felt to be knowable instruments but in the light of the present crisis produced instead 'unbundled, practically unknowable financial assets'. The visualization techniques in other words may lead to the illusion that the future is knowable because it can be 'seen'. Yet in truth, with innovations such as options, 'correct' pricing can be achieved only *ex post*, when, that is, actual volatility and distribution are known at maturity. Too much belief in the pictures may well have contributed to excessive innovation and the subsequent irrational meltdown of the financial system.[20] A similar wish to anticipate future market events lies at the heart of the next visualization techniques discussed below.

Visualizing US Treasuries: 'getting closer to the market ... to an actionable event'

The US Treasuries securities market is a key global financial market.[21] This pivotal position revolves around its centrality to other major markets which use Treasury yields as a benchmark price for judging and pricing a range of other debt securities. Additionally US Treasuries act as a conduit for US and thus global economic information. US government macro-economic policy and monetary policy, the repercussions of international geopolitical events and the tremors from 'distant' financial market crises, for example, turn up as number in New York. Given their market significance it is hardly surprising that Treasuries are 'analyzed for the *information they might reveal* about market participants' expectations about the future path of the [US and the world] economy and monetary policy' (Dupont & Sack, 1999, p. 785, emphasis added). As was explained to me, traders in these markets are 'position-centric': a market participant's expectations revolve around the question of 'where can I get in and out of a trade?' (interview; see also Zaloom, 2009). This contrasts with equities, for example, where the analysis focuses on whether a stock is over- or undervalued and on relative performance (as the next section suggests). Hence in the Treasuries markets a very particular combination of meanings is looked for in the data, around which the visualization software has been developed.

To explain, in the Treasuries markets the task of analysing, of making sense of what is going on, of being sure about what price shifts mean immediately and in the 'near future', judging moods and expectations and thus when it is best to trade ... are all practices that are swiftly complicated in fast-moving,

real-time markets where the volume and frequency of trades are staggering. Five-year notes for example, the most frequently traded of US Treasury Securities, had a mean of 687 daily trades per day between 1996 and 2000. Over the same time period, the mean daily volume of trades in the two-year note was US$6.8bn; the volume of trades in this note reached just over US$12bn in the autumn of 1998, the year which saw the Russian financial crisis and the bail-out of LTCM (which had substantial positions in US Treasuries) (Fleming, 2003, pp. 87–9; Dupont & Sack, 1999) reverberate through the Treasuries markets.

Moreover, in the all these markets – from primary and secondary markets through to derivatives based on the price of these securities – one significant issue is foremost in the interpretation of market movements. This issue revolves around the nature and quality of the bid or the offer, and, relatedly, judging the factors that contribute to liquidity at any one time. For market practitioners then to understand what factors contribute to liquidity is simultaneously to gain a better insight into price formation. The goal of designing visualization software for the Treasury securities markets is to enable market participants to see trading volume and frequency, bid-ask spreads, quote sizes, trade sizes, on and off-the-run yield spreads ... more clearly.[22] Although the information may well be in the numbers, the design task is to facilitate its extraction and turn it into market knowledge in ways that help participants more fully to sense market developments in real time and to act, to intervene, appropriately by executing a buy or sell decision.

The attractiveness of software that re-presents the board prices in a clearer visual form is suggested in the wording of the earlier quote where the emphasis was placed on the 'analysis of yields' so as to 'garner information hidden in them' and better informing 'market participants' expectations about the future' (interview). Visualization software for this market has been designed to aid better judgement about how others view the future, what bids and offers might mean; in brief to help participants 'act intuitively', to get 'closer to the market, to an achievable event' that is unfolding as number across their screens (interviews).

Conventionally, participants see the market represented as a 'quote board' (Figure 2). This is a box of numbers arranged in columns and rows and labelled accordingly, which is still the dominant way that prices are seen. The latest software in this market transforms the flat data into colourful representations of market movements and features (Figure 3). The colours and shapes of the columns or stacks change like a carousel as market action develops. The software provides a choice of views; it is possible to focus on all Treasury instruments (from the two-year to the thirty-year view) or simply focus on one instrument. The re-presentation of numbers is designed to help participants see more exactly where the market is and what the market patterns are (Figure 4); the best bid/offer can be viewed and 'moused over' to see market depth behind the bid or stack.

Quote Board - Cantor G3 Vision

	Market View			Bid/Ask Yield	Last Price	Chg	Last Yld	Hi Price	Lo Price	Close
usg_02Y	99.126 -	99.130	4x180	4.702-697	99.130	-0.02	4.697	99.152	99.126	99.150
usg_03Y	99.166 -	99.170	2x46	4.673-670	99.166	-0.03+	4.673	99.206	99.166	99.202
usg_05Y	98.166 -	98.170	10x50	4.589-588	98.166	-0.06	4.589	98.22+	98.16+	98.226
usg_10Y	99.14+ -	99.150	35x37	4.569-567	99.150	-0.07+	4.567	99.23+	99.14+	99.22+
usg_30Y	99.14+ -	99.160	1x3	4.533-531	99.15+	-0.13	4.532	100.010	99.15+	99.28+
2Y Mar 06	102.036 -	102.040	751x3463		102.040	-0.02		102.090	102.036	102.060
5Y Mar 06	105.060 -	105.06+	2713x1715		105.060	-0.05		105.11+	105.060	105.110
10Y Mar 06	107.28+ -	107.290	1252x666		107.28+	-0.07		108.050	107.28+	108.03+
30Y Mar 06	112.250 -	112.260	1571x96		112.260	-0.08		113.050	112.250	113.020
usg_02Y/TUH6_EDB	-2.232 -	-2.226	4x150							
usg_03Y/FVH6_EDB	-5.216 -	-5.210	2x46							
usg_05Y/FVH6_EDB	-6.216 -	-6.210	10x50							
usg_10Y/TYH6_EDB	-8.14+ -	-8.13+	35x37							
usg_30Y/USH6_EDB	-13.11+ -	-13.090	1x3							
usg_02Y/3Y	3.250 -	-2.250	4x2							
usg_02Y/5Y	11.500 -	-10.750	4x10							
usg_02Y/10Y	13.500 -	-12.750	4x35							
usg_02Y/30Y	17.250 -	-16.250	3x1							
usg_03Y/5Y	8.750 -	-8.000	2x10							
usg_03Y/10Y	10.750 -	-10.000	2x35							
usg_03Y/30Y	14.250 -	-13.500	2x1							
usg_05Y/10Y	2.500 -	-1.750	10x35							
usg_05Y/30Y	6.000 -	-5.250	3x1							
usg_10Y/30Y	4.000 -	-3.250	3x1							

Figure 2 Quote board

For instance, it is possible to see the make-up of the 'stack' or total bid of, say, US$117m (the screen will show up to the top five bids making up the total) (Figure 5). The design enables both interaction and the ability to 'see through bids and offers'. The screen may show where other market participants are – the flashing screen will reveal the number of people putting in an offer at any one price – and the type of bid or offer. In the words of a representative of the software developer, the visualization enables someone to:

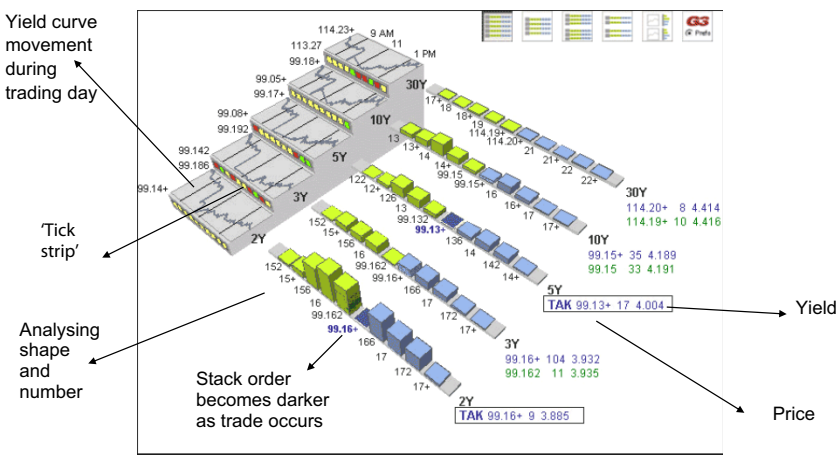


Figure 3 Two- to twenty-year view (full-colour version available online)

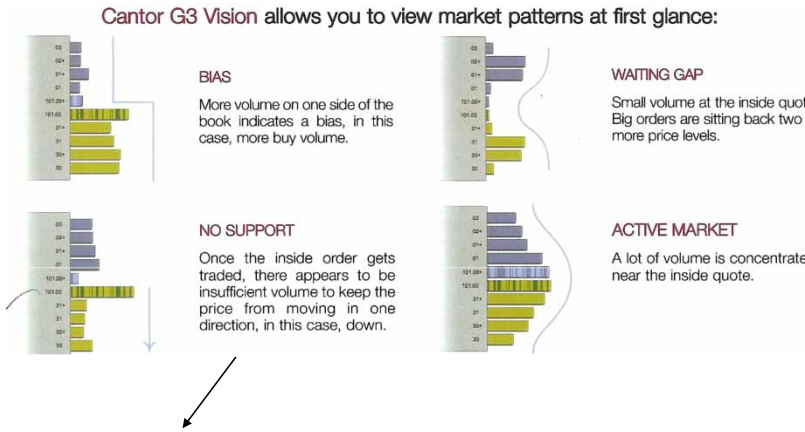
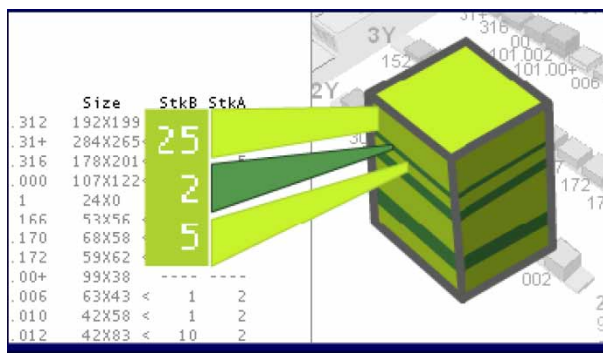


Figure 4 Market patterns: bias, support, liquidity (full-colour version available online)

see numbers flashing and turn ... to see depth, bias, where there is support ... positions behind best bid/offer. Is there active market support in the stacks? You can see there's a waiting gap ... there's more bias on offer side ... waiting to see there's US$250m [bid/offer] but [you can see that] nobody else is there. On the [price] board you would really have to look at the numbers ... 18 +, $18\frac{3}{4}$ ... work at it ... to see someone in the stack who is just trying to offload or someone putting in a bogus bid ... but you can see this using the visualization techniques. A lot is happening and trying to process that in your head, trying to see the bias, is difficult. See what the market is doing trying to anticipate your



• Height and number of bands communicate the number of participants and size of individual order, indicating 'true' liquidity

Figure 5 Seeing the 'stack' (full-colour version available online)

> next move ... [The software helps to visualize the] same prices [as are shown on the board] but [offers a] different way of looking at them ... particularly [useful] to a trader who is say in equities but needs to see quickly what is going on in Ts. See last ten trades ... thus get better idea of what market is doing. As a lot more markets move to electronic rather than voice, then have to get an edge somewhere.
>
> (interview)

This suggests that this form of visualization is one stage on from that used by Zaloom's futures traders where '[t]he numbers consolidate the image of the market on a trading screen; in those numbers, traders confront only the aggregate market they receive through their computers, not an image of the human competitors' (2006, pp. 174–5). Here, the software seeks to get behind the numbers, as it were, precisely to sketch the competitor and their likely intentions and motives, and the consequent impact on market prices. As another software developer involved in this market put it: 'Visualization techniques assist in the task of making inferences – which in many ways is what it's all about' (interview).

And getting an edge means being able to manipulate in an effort to reveal meaning. For instance, so-called handles are available to 'turn the market' and move it around the screen; it is possible to enlarge the dedicated screen when prices on the quote board (shown on a neighbouring screen) signal the need to look at what is causing the prices to change rapidly. This feature may be of use to those dealing directly in Treasuries or equally to those who hold instruments, other debt, the price of which may be influenced by what happens in Treasuries. The screen display uses colour as well as changing shape to indicate market action; when there is activity, for example, the inside stacks will get darker when there is a hit or a take, indicating a trade; changing colours and moving stacks aid faster and easier processing of market developments.

With Treasuries futures, market participants are interested in slightly different features of the market than is the case in the secondary market. What the participants in futures want to see in particular is the basis spread and, although there is no actual trade state to be seen (as was the case with the on-the-runs, above), they will also still want to see positions and stacks, an intraday chart and a ticker strip.

The visualization software again serves as a way of displaying market depth as well as expressing important relationships; it is possible to chart two-year futures against the ten-year futures, or the two-year future versus the cash (Figure 6). The significant thing is that once prices are turned into pictures it is easier to 'keep an eye on them to see how they are running against each other' (interview). Moreover, because of the interactive nature of the software, there is choice as to what is seen and which instruments are calculated against each other to show whatever spreads are of interest: switch, for instance, into a spread view to see basis spread then click (the brown or grey slab) and see ten-year cash basis spread and so on (Figure 7).

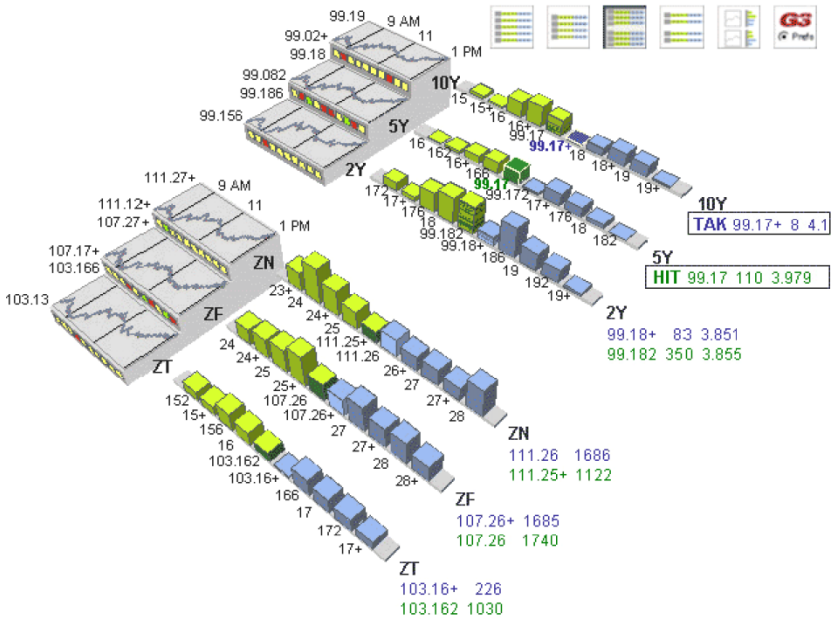


Figure 6 Futures (full-colour version available online)

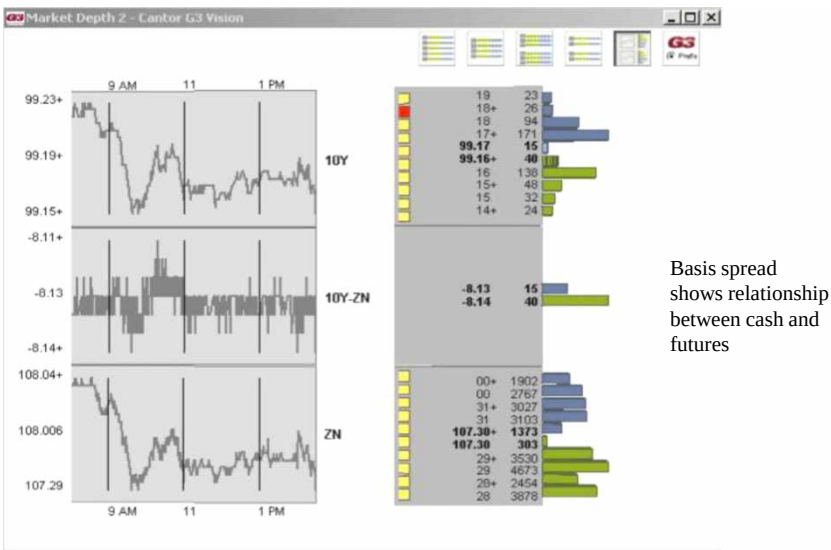


Figure 7 Seeing the spread (full-colour version available online)

The visualization software discussed in this section suggests that the market, as an actionable event achieved through the interaction of many changing components, is prepared by a process of addition and dissection, manipulation and seeing, as the user desires, like all the other participants, to negotiate the future profitably. Significantly, the market participant is 'not left with numbers alone'; all key aspects of the market can be shown on one screen; full vision of the market is achievable (see Figure 8). Moreover, each representation is open to closer scrutiny by a simple click, thus supposedly making it easier to guess the expectations of others in the market, as Keynes might add.

'It's all about market watching – but not losing peripheral vision'

The last example focuses on software that aims to help market participants refine and reflect on market movement and the associated data. The software focuses on enabling the judgement of relative performance, 'value' and risks and perhaps reflects well financial organizations' underlying collective 'ambition to control and managerialise the future' (Power, 2004, p. 59). As noted in the introduction, the main issue facing financial organizations today is not access to data but what to do with them; organizations wish to move from having vast silos of data (compiled using business intelligence software) to a position where they are able to filter data and to ask questions of the data,

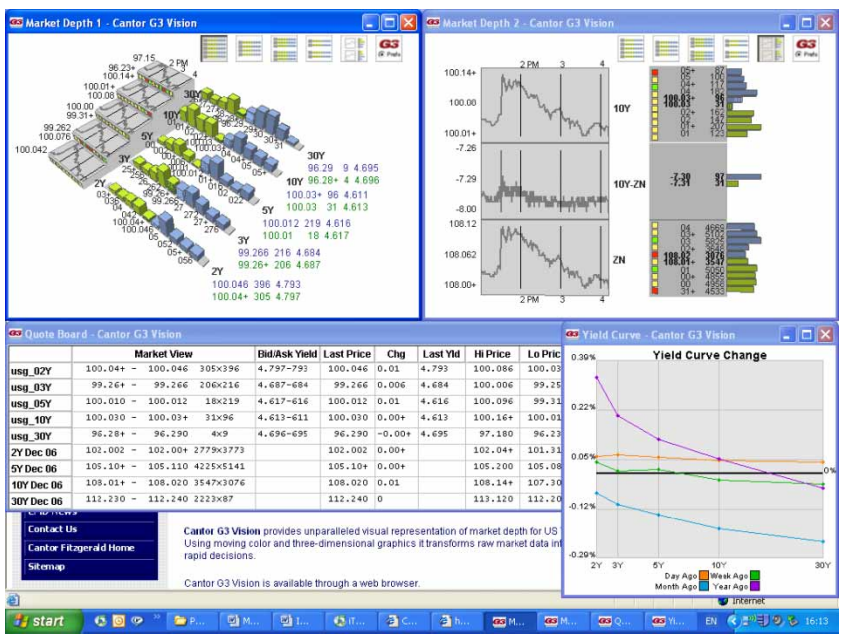


Figure 8 Full vision (full-colour version available online)

rather than simply be presented with a mass of numbers. 'Financial firms wish to mine data. They need to do so quickly; the Excel presentation of data meant that it was a slow process of finding out what is going on within a firm, where the risks are, how market movements may develop and affect a firms' profits. Time is important' (interview).

As this suggests, this type of visualization software is designed to help financial firms to get to '*know* risks', and to ask questions about risk positions that might not have previously been posed, as they, along with so many other organizations, become organizationally more reflexive (Power, 2007, p. 4). Once captured visually, risks can then be seen as 'objects' and subjected to 'action and intervention', a strategy that is part of a broader organizational trend identified by Power to put in place practices to represent, frame and handle risk (2007, p. 4); although, as he notes, the end-game is a paradoxical desire to 'to know the unknowable' (Power, 2004, p. 59).

Seemingly unaware of this paradox, the visualization software discussed in this example has been used in equities, fixed income and foreign exchange markets with the precise aim of making the future knowable and thus risks – chiefly market, credit and operational – manageable.[23] Common to all of these applications is the refinement of market information. Such refinement is achieved by transforming seeing into, to borrow from Alac, a 'process' that recombines the technology, practices and settings as well as the market participants' 'embodied accounts' (2008, p. 503). Learning how to do global finance, getting to know risks, how they may develop and move through highly spatialized markets represented in novel ways on screens, involves learning the practicalities of seeing. The practicalities in the example below involve using visualization software to break down 'drill through' aggregate data to allow analysis, for example, of individual component companies within an equities index, within a sector and subsector, and for the related numbers showing performance (such as volume of trades in a company's stock, the latest bid price, price/earnings ratios and so on) to be shown alongside pictures; the numbers and number-as-picture sit side by side on the screen (Figure 9 and 10).

To expand: the software breaks the world into three main regions – Europe, the Pacific Rim and North and South America. By moving a computer mouse, the display is made to close in on an index, for example the IBEX 35; then, click again to get to a sector, all the way through to individual stock and its contribution to the sector's performance and the index. The technique assists the user to see how much of this particular company's stock is held, for example, by an investment bank. The attraction is that the screen works through colour and shapes but also gives the user instant access to the data, the all important numbers. So it is possible for the bank to see that although the IBEX 35 may be doing well, the relative buoyancy is actually being driven by the non-cyclical consumer sector. Similarly, if the Nikkei is doing badly it is possible to drill down to see that within it the energy sector is bucking the trend: 'It's all about market watching ... being able to see the market' (interview) and to see what might happen to the market if conditions change

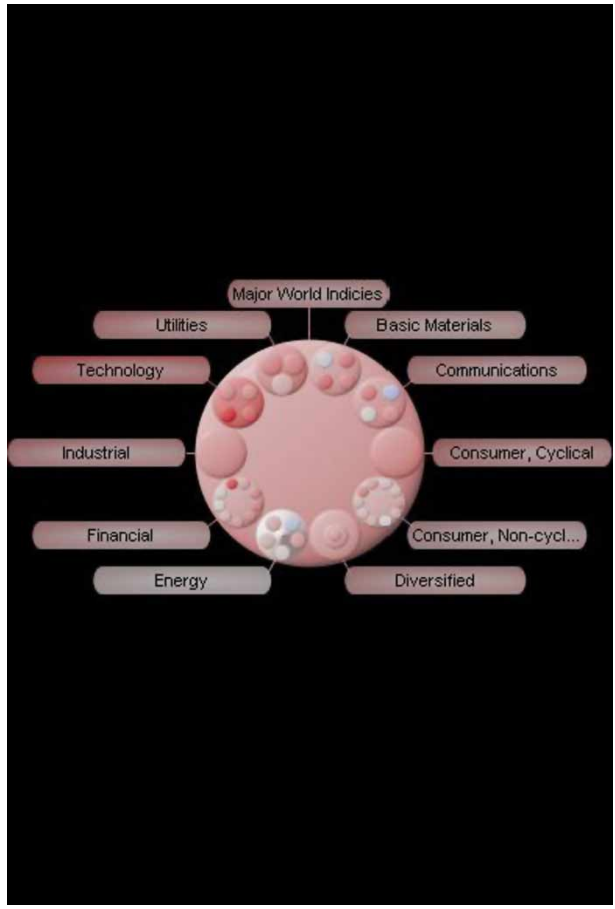


Figure 9 Mining for information (full-colour version available online)

for the worse; to see, in other words, according to other criteria. By recalculating data according to new criteria in effect a 'new' market is displayed as altered colour and shape.

Reflecting a 'myth of control' and responding to what Power refers to as a general 'demand for decisions in areas where some pretence of knowledge is a necessary defence against anxiety' (2004, p. 59) one software designer explained that the ambition was to design into the software the ability to 'see what is just around the corner that may affect a bank's profits' (interview) but to do so in ways that do not obscure important data. In light of the financial crisis this was clearly very wishful thinking. Yet arguably such a wish discloses a lot about how risk management techniques have blurred risk and uncertainty and how both have been approached more recently within financial markets. As Power has noted, under present risk management techniques and risk

Figure 10 Slicing and seeing through the trades (full-colour version available online)

discourse '[u]ncertainty is ... transformed into a risk when it becomes an object of management, regardless of the extent of information about probability ... When uncertainty is organized it becomes "risk" to be managed' (2007, pp. 5–6). Visualization software is part of the technological armoury used to transform uncertainties into risk objects thus 'rendered thinkable, and made amenable to processes and practices of intervention' (2007, p. 9). The use of such software by one leading global investment bank to help it cope with its equity risk management at a global level is illustrative of these points.

To work effectively a bank may set limits on the percentage of funds in *x*, *y* and *z* sectors or regions, for example, yet in order to make profits the bank has to allow its traders to take risks – quite obviously that is how they make their money. Contributing to the problem is the criss-crossing of financial markets,

noted earlier, which means that, in the process of trading, traders increasingly may be buying complicated products that run across many different risk categories and profiles. The maps help those in charge of risk management to 'see through' trades to work out the risks, their nature and potential impact on the whole bank's operations, and to do this on an ongoing basis. This is not possible in real time as to attempt this would simply be too complicated. Thus at the end of the trading day data are collected centrally by the bank and calculations are run overnight. The bank will run 'scenarios' – such as what happens if certain markets go up by 1 per cent, while others go down by 2 per cent? What happens if the Fed hikes interest rates – what will this do to holdings in Southeast Asia? So, what is being calculated is the original dataset multiplied by, for example, six different scenarios. What the software allows is for the risk associated with each scenario (for example, if rates rise by 3 per cent) to be seen and identified, rendered thinkable because it has been rendered visual – 'the problem is here' (interview) – hence made 'amenable to intervention'.

As this example suggests, the way the visualization software has been designed to help in the interpretation of data and thus to aid market participants to anticipate where a problem may arise, and what needs to be done in the market to avert the danger, strongly suggests a collective belief that in 're-cognizing' risks (and uncertainties now re-organized as risks) through visual techniques, the future has in many respects been tamed and made manageable. In the light of the present financial crisis however this belief is at least questionable, not least because, as the crisis demonstrates, financial market operations today involve trying to calculate highly spatialized futures. To attempt to see market developments and risks clearly through such complex, continually emergent financial topologies is never going to be that straightforward, no matter how good the software.

Conclusion

In seeking to locate the growth in the use and development of visualization software in financial markets this paper raises more questions than it can answer. Three brief points will be made by way of conclusion and they are made in a speculative manner and are an attempt to make sense of the latest visualization software, its impact on financial markets and some possible wider research issues.

First, there is the issue of the incorporation of the visual into thinking about the formatting and preparation of financial markets, how markets work and the consequences. That is, the types of software referred to in this paper serve to enhance the visual sense as a central component in the ongoing practices that surround and inform the development of contemporary financial markets. The outcome is not about transforming numbers into pictures alone. As an integral 'device' in enabling action in key financial markets, such as US Treasuries and global equities, clearly the software-as-device 'does things' (Muniesa *et al.*,

2007); the software is neither 'dead instrument' (Preda, 2005, p. 627) nor 'neutral device' (Kalthoff, 2005, p. 71) (nor is it free from politics [Crang & Graham, 2007]). One of the things that it does or certainly enables is what David Stark refers to as the 're-cognition' of market action. This is achieved in various ways, such as the transformation of number into pattern and the ability then to manipulate market developments into visual forms that allow market action to be reinterpreted in more meaningful ways than if number alone were the cue. Yet what the present research suggests is that financial markets, as an unfolding series of interlinked computations, risks and uncertainties, can now be looked at in multiple dimensions that aid greater visual absorption of market information. The numbers, the 'natural representation of financial markets', remain central, of course. What the numbers signal, what prices and risks (might) mean, however becomes more of a visually engaging and imaginative affair. The greater incorporation of visual techniques into market practices suggests strongly that market participants are offered new procedures for the analysis of markets, and thus new ways to think about, for instance, the interrelationships between market components and thus (echoing an earlier section) potentially altering the contours of financial knowledge formation. How all this develops in the near future, and the consequences, are clearly matters for further research. Such research might wish to broaden the inquiry to examine ethnographically the sociocultural and technical practices into which and around which new visualization techniques are introduced. This leads into a closely related issue.

The second issue centres on how to progress further research into the greater reliance on the visual currently being built into the ways in which financial markets are prepared and work. If this is a goal, then more attention needs to be paid to what could be called the materiality of the visual – the stuff, that is, the software, the screens, the algorithms and so on, that all together make the visualizations work – *and* crucially the forms of sociation (the organization of the human material, if you will), the practical activities, that help make sense of the revisualization of markets. This seems crucial but for one reason or another is an undeveloped area (with the exceptions noted in this paper). The markets that are being formed through visualization techniques are not after all shaped by the software alone, just as the processes turning numbers into patterns should not be reduced to a question of representation.

Lastly, it seems clear that visualization software and techniques for re-visualizing financial market data are being taken very seriously within financial markets. Witness the growth in the number of software developers working actively with financial organizations to develop visualization techniques to help leverage a bank's existing data management and proprietary data feeds, such as key trade indicators, and the growing number of specialist 'computational architecture groups' within large and complex financial institutions, such as JP Morgan Chase, responsible for progressing and innovating visualization techniques within their organization. This would suggest that financial market participants' collective interest in preparing markets so as to emphasize the

visual sense as they try, through visual experimentation to search for actionable knowledge, for example, to help make sense of what is going on, should now be matched amongst those social scientists interested in exploring the making of financial markets and the consequences of an increasingly financialized world.

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Notes

1 See Appendix 1 for details of interviewees and methods.

2 See Muniesa *et al.* (2007) for a helpful introduction to the notion of market devices and the surrounding literature.

3 So-called rainbow options are examples of such instruments (see Ouwehand & West, 2006, p. 79; see also 'Enter the quants . . . ' section).

4 This is not to say that the visualization techniques introduced to help cope with risk are not potentially the source of more risk. As financial organizations seek to deal with risks and uncertainties they are undoubtedly caught in what Hutter and Power (2005, p. 3) refer to as a 'double movement': as financial agents seek to organize for risks they undoubtedly produce further risks – no doubt the result of 'the unintended side-effects of risk management systems' (Holzer & Millo 2005, p. 242) – for themselves and significantly for others, as the present crisis shows only too well.

5 The paper offers only a limited set of examples and it is important to stress that the examples are illustrative of general trends among financial market participants based in London and New York. Even within these admittedly key locations 'fragmentation rules' as one software developer commented (interview): markets and organizations, teams within organizations and individuals within teams may well all want to see different parts of 'their' market.

6 Interest in the formation and workings of financial markets is growing rapidly. There has been considerable work by those working within the social studies of finance, such as that by Donald MacKenzie, Karin Knorr Cetina, Alex Preda, David Stark and Daniel Buenza, Fabian Muniesa and Yuval Millo, for example. Social anthropologists, led by Bill Maurer, Annelise Riles and Hiro Miyazaki and Caitlin Zaloom, have

produced fascinating ethnographies of key aspects of how financial markets work; political economists such as Dick Bryan and Michael Rafferty have turned their attention to derivatives in particular, while sociologists in the UK, such as Geoff Ingham and Nigel Dodd, and economic sociologists in the US, such as Mitchel Abolafia, Neil Fligstein and Bill Carruthers, and Jocelyn Pixley (in Australia) have all engaged money and finance in a long list of publications. Marieke de Goede's research signals an interesting take on finance from within international politics.

7 See also Daniel Beunza's work with Fabian Muniesa (Beunza & Muniesa, 2005) and his work with a variety of artists (Beunza, 2006; Canet *et al.* 2006).

8 Visualization software and screens are understood in this paper as technical artefacts. As Kroes and Maijers helpfully clarify, such artefacts differ from physical or natural objects as they are 'intentionally produced by human beings to realize certain goals'. As they go on to refine their definition, these artefacts are 'produced in the sense that it is only in relation to human intentionality that physical objects become technical artefacts ... they are objects to be used for doing things and are characterized by a certain "*for-ness*". It is this teleological element that sets technical artifacts apart from physical objects' (2006, p. 1, emphasis added). The introduction and application within financial organizations of the types of visualization software discussed here (often developed originally in fields as distant as geology and medical research) is where and how it acquires its 'for-ness'. The software gains for-ness through integration into the forms of sociation characteristics of each financial market and the various sociocultural-technical practices that continually make it up.

9 As Preda (2009, pp. 684–5) notes in his recent work on online traders, what is involved is more than mere looking; active bodily work is part of the work of calculating what the screen displays. There is an interesting and growing body of literature on the use of magnetic resonance imaging in medical research that raises many questions about 'gestural engagements' in the interface between the technology and screens and 'embodied action', as well as how knowledge is shaped through seeing, all of which are pertinent to understanding the influence of visualization techniques on financial market practices and the production of financial knowledge (see, for example, Alac, 2004, 2008; Alac & Hutchins, 2004; Joyce 2006).

10 The words are those of a strategist specializing in financial risk for Banking and Capital Markets, Microsoft Financial Services (*Wilmott*, 2006, p. 14).

11 Software, as Thrift and French (2002, p. 310) have noted, too often sits in the background, as it were, unnoticed (see also Knorr Cetina 2003, p. 9; Thrift 2004a).

12 In an interesting paper Klamer goes back to Schumpeter to remind us that 'Economic theorizing begins with a vision'. The way Klamer develops this is to link the constitutive metaphors and narratives of economics to visions. Following Rorty, he argues that vision 'informs and is represented by the metaphors that constitute a conversation, the so-called constitutive metaphors' which 'underlie all thinking to such an extent that thinking without them is inconceivable' (2004, p. 259). Metaphors reflect visions held by economists; and, like metaphors, visions are constitutive of conversations (see Klamer, 2004) about how, for instance, the workings of financial markets and 'the world' are/should be talked about and the consequent acts that follow. Visualization techniques allow those conversing to be surer of their ground. Note how Knorr Cetina refers to markets in foreign exchange, the first screen-based financial market (2003, pp. 14–15), as a 'large, globally distributed conversation' (Knorr Cetina & Bruegger 2002a, p. 914).

13 Knorr Cetina and Bruegger (2002b) argue that the screen world is a flow world made this way by technologies; they ask: what is the 'material' of a system that is located entirely in the symbolic space of an electronically mediated reality? (As they note elsewhere, the screens do not, in their core elements, represent a reality 'out there', but are 'constitutive of it' [2000, p. 166]). Knorr Cetina and Bruegger emphasize the

'textual' character of this world: writing ... on the screen. This they argue leads to the identification of the secondary economy of 'hardware developments and writing (news etc.) that is also a form of "world-making". Other traders provide the writing ... prices, gossip ... as they "perform the market on screen"; the representational part of screens brings the world electronically on to screens ... they emphasise news (rather than "confirmed correspondence with world"), *information is the materiality of the screen world*' (Knorr Cetina & Bruegger, 2002c, pp. 401–402; emphasis added).

14 'In the phenomenon of screen, seeing is not merely being aware of a surface. The very watching of the screen as screen implies an already present ontological agreement about the nature of the world; a world that is relevant (and true) to us who share it, in and through the screening of the screen' (Introna & Ilharco, 2006, pp. 69–70). This is part of an 'an already implied and agreed way of being' (2006, p. 71).

15 Visualization techniques may be used by, say, two out of an eight-strong portfolio team. Six of the team will be focused on particular strategies with two using visualization software as a guide focusing on global level developments (interview with investment bank representative).

16 The use of generally available data is important as financial institutions will always, of course, be interested in liquidity. These data may be informed by use of in-house-generated data in an attempt to get an edge.

17 The equation can be solved by using a numerical solution provided by specialist companies such as NAG Ltd that are able to supply routines to aid derivative pricing and specific Black-Scholes 'solvers' which calculates the price and derivatives (the so-called Greeks). In what follows I am referring to swaptions rather than standard options.

18 I am grateful to Dr Jeremy Walton, NAG (Numerical Algorithms Group), for talking me through examples of how software might be adapted to aid the visualization of the 'solution', that is the dataset (interview 1 November 2006).

19 The smile can be thought of 'as a pattern of option prices in which the graph of the relationship between strike price and implied volatility is not a straight line, as it should be on the Black-Scholes model (or the analogous surface is not a plane, if we are dealing with more complicated options)' (Donald MacKenzie, pers. comm. 8 January 2007).

20 I am very grateful to one referee for pointing this out and for providing the technical guide.

21 In 1999 the amount of Treasury debt held in non-federal government accounts stood at around US$36 trillion (more or less the total for outstanding debt securities issued by all US corporations at that time [Dupont & Sack, 1999]).

22 See Fleming (2003) for an in-depth analysis of Treasury market liquidity; see also Fleming (1997), Edwards and Ma (1992), and Fabozzi and Modigliani (1996).

23 See Power (2005) for a full discussion of operational risk.

References

Alac, M. (2004). Negotiating pictures of numbers. *Social Epistemology*, *18*(2–3), 99–214.

Alac, M. (2008). Working with brain scans: Digital images and gestural interaction in fMRI laboratory. *Social Studies of Science*, *38*(4), 483–508.

Alac, M. & **Hutchins, E.** (2004). I see what you are saying: Action as cognition in fMRI brain mapping practice. *Journal of Cognition and Culture*, *4*(3), 630–61.

Amin, A. & **Thrift, N.** (2004). *The Blackwell cultural economy reader*. Oxford: Blackwell.

Beunza, D. (2006). New artistic engagements with capital markets. *Economic Sociology European Electronic Newsletter*, *7*(3), 29–33.

Beunza, D. & **Muniesa, F.** (2005). Listening to the spread plot. In B. Latour & P. Weibel (Eds.), *Making things public: Atmospheres of democracy* (pp. 628–33). Cambridge, MA: MIT Press.

Beunza, D. & **Stark, D.** (2004). Tools of the trade: The socio-technology of arbitrage in a Wall Street trading room. *Industrial and Corporate Change*, *13*, 369–400.

Beunza, D. & **Stark, D.** (2005). How to recognize opportunities: Heterarchical search in a trading room. In K. Knorr Cetina & A. Preda (Eds.), *The sociology of financial markets* (pp. 84–101). Oxford: Oxford University Press.

Callon, M., **Millo, Y.** & **Muniesa, F.** (Eds.) (2007). *Market devices.* Oxford: Blackwell/Sociological Review.

Canet, M., **Rodriguez, J.** & **Beunza, D.** (2006). Derivatives: New financial art visions. Retrieved from http://www.derivart.info/index.php?s=derivados&lang=en

Clark, G. L. (2005). Money flows like mercury: The geography of global finance. *Geografiska Annaler, Series B: Human Geography*, *87*(2), 99–112.

Clark, G. & **Thrift, N.** (2005). The return of bureaucracy: Managing dispersed knowledge in global finance. In K. Knorr Cetina & A. Preda (Eds.), *The sociology of financial markets* (pp. 229-50). Oxford: Oxford University Press.

Crang, M. & **Graham, S.** (2007). Sentient cities: Ambient intelligence and the politics of urban space. *Information, Communication and Society*, *10*(6), 789–817.

Das, S. (2006). *Traders, guns and money.* London: FT Prentice Hall.

Dupont, D. & **Sack, B.** (1999). The Treasury securities market: Overview and recent developments. *Federal Reserve Bulletin*, *85*, 785–806.

Edwards, F. R. & **Ma, C. W.** (1992). *Futures and options.* London: McGraw Hill.

Engelen, E., **Ertuk, I.**, **Froud, J.** **Leaver, A.** & **Williams, K.** (2009). *Toxic innovation? Beyond Haldane's gambit*. Paper presented at 'Political Economy, Financialization and Discourse Theory' Conference, Cardiff Business School, Cardiff.

Fabozzi, F. & **Modigliani, F.** (1996). *Capital markets* (2nd ed.). London: Prentice Hall.

Fleming, M. J. (1997). The round-the-clock market for US Treasury statistics. *FRBNY Economic Policy Review*, July, pp. 9–32.

Fleming, M. J. (2003). Measuring Treasury market liquidity. *FRBNY Economic Policy Review*, September, pp. 83–108.

Graham, S. (2005). Software sorted geographies. *Progress in Human Geography*, *29*(5), 562–80.

Higgins, D. (1998, September 6). Visualizing financial markets. Retrieved May 17, 2005, from www.fenews.com/fen6/visualizing.html.

Holzer, B. & **Millo, Y.** (2005). From risks to second-order dangers in financial markets: Unintended consequences of risk management systems. *New Political Economy*, *10*(2), 223–45.

Hughes, J. & **Baxter, A.** (2005, August 16). The new tools of the trader. *Financial Times.*

Hutter, B. & **Power, M.** (2005). Organizational encounters with risk: An introduction. In B. Hutter & M. Power (Eds.), *Organizational encounters with risk* (pp. 1-32). Cambridge: Cambridge University Press.

IMF (2006, September). Assessing global financial risks. In *Global financial stability report*. Retrieved from http://www.imf.org/External/Pubs/FT/GFSR/2006/02/index.htm

Introna, L. D. & **Ilharco, F. M.** (2006). On the meaning of screens: Towards a phenomenological account of *screenness. Human Studies*, *29*, 57–76.

Joyce, K. A. (2006). From numbers to pictures: The development of magnetic resonance imaging and the visual turn in medicine. *Science as Culture*, *15*(1), 1–22.

Kalthoff, H. (2005). Practices of calculation: Economic representations and risk management. *Theory, Culture and Society*, *22*(2), 69–97.

Klamer, A. (2004). Visualizing the economy. *Social Research*, *711*(2), 251–62.

Knorr Cetina, K. (2003). From pipes to scopes. *Distinktion*, *7*, 7–23.
Knorr Cetina, K. & **Bruegger, U.** (2000). The market as an object of attachment: Exploring postsocial relations in financial markets. *Canadian Journal of Sociology*, *25*(2), 141–68.
Knorr Cetina, K. & **Bruegger, U.** (2002a). Global microstructures: The virtual societies of financial markets. *American Journal of Sociology*, *107*(4), 905–50.
Knorr Cetina, K. & **Bruegger, U.** (2002b). Traders' engagement with markets: A postsocial relationship. *Theory, Culture and Society*, *19*(5–6), 161–85.
Knorr Cetina, K. & **Bruegger, U.** (2002c). Inhabiting technology: The global lifeform of financial markets. *Current Sociology*, *50*(3), 389–405.
Kroes, P. & **Maijers, A.** (2006). The dual nature of technical artefacts. *Studies in History and Philosophy of Science Part A*, *37*(1), 1–4.
Latham, R. & **Sassen, S.** (2005). Digital formations: Constructing an object of study. In R. Latham & S. Sassen (Eds.), *Digital formations* (pp. 1–34). Princeton, NJ, and London: Princeton University Press.
MacKenzie, D. (2006). *An engine, not a camera: How financial models shape markets*. Cambridge, MA, and London: MIT Press.
MacKenzie, D. (2007). Zero is a clenched fist. *London Review of Books*. Retrieved from http://www.lrb.co.uk/v29/n21/mack01_.html
MacKenzie, D. & **Millo, Y.** (2004). Constructing a market, performing theory: The historical sociology of a financial derivatives exchange. *American Journal of Sociology*, *109*(1), 107–45.
Miyazaki, H. (2007). Between arbitrage and speculation: An economy of belief and doubt. *Economy and Society*, *36*(3), 396–415.
Muniesa, F., Millo, Y., & **Callon, M.** An introduction to market devices. In M. Callon, Y. Millo & F. Muniesa (Eds.), *Market devices* (pp. 1-12). Oxford: Blackwell/The Sociological Review.
Ouwehand, P. & **West, G.** (2006). Pricing rainbow options. *Wilmott*, May, pp. 74–80.
Panopticon (2005). *Panopticon software: Information visualization software*. Conceptual white paper, Version 2.1.2. Sweden: Panopticon Software.
Power, M. (2004). *The risk management of everything*. London: Demos.
Power, M. (2005). The invention of operational risk. *Review of International Political Economy*, *12*(4), 577–99.
Power, M. (2007). *Organized uncertainty: Designing a world of risk management*. Oxford: Oxford University Press.
Preda, A. (2005). The stock ticker. In B. Latour & P. Weibel (Eds.), *Making things public: Atmospheres of democracy* (pp. 622–7). Cambridge, MA: MIT Press.
Preda, A. (2009). Brief encounters: Calculation and the interaction order of anonymous electronic markets. *Accounting, Organizations and Society*, *34*, 675–93.
Pryke, M. & **du Gay, P.** (2007). Take an issue: Cultural economy and finance. *Economy and Society*, *36*(3), 339–54.
Sassen, S. (2002). Towards a sociology of information technology. *Current Sociology*, *50*(3), 365–88.
Sassen, S. (2004). The locational and institutional embeddedness of electronic markets. In M. Bevir & F. Trentmann (Eds), *Markets in historical contexts: Ideas and politics in the modern* world (pp. 2224–46). Cambridge: Cambridge University Press.
Taylor, P. (2004). *World city network*. London: Routledge.
Thompson, G. (1998). Encountering economics and accounting: Some skirmishes and engagements. *Accounting Organizations and Society*, *23*(3), 283–323.
Thrift, N. (2004a). Remembering the technological unconscious by foregrounding knowledges of position. *Society and Space*, *22*, 175–90.
Thrift, N. (2004b). Movement-space: The changing domain of thinking resulting from the development of new kinds of spatial awareness. *Economy and Society*, *33*(4), 582–605.
Thrift, N. & **French, S.** (2002). The automatic production of space.

Transactions of the Institute of British Geographers NS, *27*, 309–35.
Tufte, E. R. (1990). *Envisioning information*. Cheshire, CT: Graphics Press LLC.
Walton, J. (2004a). Get the picture: Visualising financial data – part 1. *Financial Engineering News*. Retrieved from http://www.fenews-digital.com/fenews/20040304/?pg=2
Walton, J. (2004b). Get the picture: Visualising financial data – part 2. *Financial Engineering News*. Retrieved from http://www.fenews-digital.com/fenews/20040505/?pg=2
Walton, J. (2004c). Get the picture: Visualising financial data – part 3. *Financial Engineering News*. Retrieved from http://www.fenews-digital.com/fenews/20040910/?pg=2
Wilmott (2006). Microsoft on creative realm of computing, analytics and visualisation in quantitative finance and financial engineering. July, pp. 14–16.
Zaloom, C. (2003). Ambiguous numbers: Trading technologies and the interpretation of financial markets. *American Ethnologist*, *30*(2), 258–72.
Zaloom, C. (2006). *Out of the pits: Traders and technology from Chicago to London*. Chicago, IL: University of Chicago Press.
Zaloom, C. (2009). How to read the future: The yield curve, affect, and financial prediction. *Public Culture*, *21*(2), 245–68.

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Appendix: methodology and interviews

Interviews were held with the representatives from the following software companies and financial organizations:

- SS&C (US-based software developer for financial markets) (telephone interview based around Webex session) 31 November 2006 (see: http://www.ssctech.com/assetmanagement/heatmaps)
- Panoptican (Swedish-based software developer for financial markets) (London Office) 12 October 2006 (see: http://www.panopticon.com)
- JP Morgan Chase (US investment bank) (New York, telephone interviews and face-to-face) 17 July 2007 and 19 December 2006 (see: http://www.jpmorganchase.com/cm/Satellite?c=Page&cid=1159304834085&pagename=jpmc/Page/New_JPMC_Homepage)
- Fractal Edge (UK-based developer of 'visualization engines' for use in financial markets) (London office) 28 September 2006 (see: http://www.fractaledge.com)
- Occulus (Canadian-based developer of visualization solutions for business including financial organizations) (telephone interview) 15 November 2007 (see: http://www.oculusinfo.com)
- BG Cantor Fitzgerald (London and New York offices) 12 October 2006 and 20 December 2006
- NAG Ltd (Oxford office) 26 October 2006 (see: http://www.bgcantor.com/index.jsp)

Each semi-structured interview lasted between one and two hours, longer in two cases. During the interviews (with two exceptions) I was shown demonstrations of the software in use and talked through examples. One interviewee took me through his company's software development via a Webex session. The selection of software companies was made following extensive background research in the specialist media, such as *Financial Engineering News* and *Wilmott*, and web searches. The companies chosen represent some of the leading companies in this field operating in the UK and North America. All interviews were conducted on a non-attributable basis.

One of the major problems with work of this sort is negotiating access. The fact that the majority of the interviews were with software companies is part design, part the result of being denied access to proprietary software and personnel within financial institutions. As Donald MacKenzie has noted: 'getting access, especially for observational work, is difficult. You're often "studying up", as anthropologists put it: researching those higher in the socio-economic scale. As a professor at a well-known university with a few letters after my name, I don't usually have trouble persuading people to let me interview them, but it's noticeably harder in financial markets than elsewhere' (2007). As I am not a professor in a well-known university, negotiating access proved a touch more difficult. In the case of two software companies I was given access to company 'white papers' on the understanding that I signed a non-disclosure agreement and refrained from drawing on such material for at least twelve months following the interview. Over the past twenty years or more of researching aspects of financial markets I have noticed that it is becoming increasingly difficult to negotiate access to financial organizations. This raises interesting questions about gaining access to people and devices producing proprietary data, and how interviews with companies in the 'secondary economy' are used to interpret primary actions, as it were, in this case those in financial organizations.