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Why derivatives need models: the political economy of derivative valuation models

Abstract

Derivatives markets continue to turnover enormous volumes and are an important part of financialised capitalism in the early 21st century. A surprising and yet key feature of these large and apparently liquid markets is that they seem to be bound up with the widespread use of mathematical valuation and risk management models by market participants. The paper investigates derivative models and risk management by highlighting the grounds for their emergence, their establishment and their influence market developments.

A political economy of derivatives markets provides insights into the essential nature of derivatives, defining them against the material circumstances in which they arise and allows the logical development of valuation models and risk management as the necessary complement to the large-scale derivatives markets that have developed since the 1980s. The paper builds from finding prices for potential new trades to valuing a completed trades and risk managing portfolios to show how and why valuation models and risk management are bound up with today's derivatives markets.

Introduction

The late 1980s marked the beginning of a new era in derivatives trading which has seen rapid growth in the volume and types of derivatives traded and the emergence, and use by market participants, of a vast literature of valuation and risk management models. Why do these huge derivatives markets require complex pricing models? After all, most commodities and other traded objects with a commodity form, from apples to zips and even other financial instruments, do not require pricing models devised by 'rocket scientists' (Stix, 1998). This paper proposes a political economy of valuation models and risk management to understand why.

Derivatives transactions predate the mathematical derivative valuation models typical since Black & Scholes (1973). Previously traders used rules of thumb (Mixon, 2009), and some argue today's valuation models are sanitised rules of thumb (Haug and Taleb, 2011). Yet in the late 1980s a change occurred that required the formalisation of these practices. This timing was not accidental: the historical emergence of risk management coincides with the growth of derivative markets from the late 1980s onwards. Figure 1 shows the instances of the word 'risk' in the titles of finance books in the British Library and Library of Congress and suggests a dramatic rise in the idea of risk management in the late 1980s/early 1990s. This period also sees the first exemption for derivatives from the Commodities Exchanges Act of 1936 in the USA which, amongst other things, required derivatives to be transacted via exchanges; subsequently a series of formal exemptions, culminating in the Commodity Futures Modernisation Act of 2000, helped encourage derivatives transacted directly between counterparts, known as over-the-counter (OTC) derivatives (Greenberger, 2010). The period also sees the first publication of OTC statistics by the International Swaps &

Derivatives Association (ISDA, originally International Swap Dealers Association) (ISDA, 2010), the first regulatory use of the word ‘derivative’ (Swan, 2000, p.9-10) and most importantly the rapid growth of derivatives markets. The notional outstanding amount of OTC derivatives, one barometer of this growth, grew from almost nothing in 1989 to over US$ 700 trillion in 2014 (Bank for International Settlements, 2014). The rise of valuation models and risk management must be located amongst these changes.

FIGURE 1 HERE

The new forms of derivative trading which have become dominant since the late 1980s appear to require valuation models and risk management; yet it is surprising that such high volume and seemingly liquid markets need a complex apparatus of mathematical models to function and to provide prices. This paper asks why the derivatives markets that have emerged since the 1980s are bound up with complex, mathematical models. The question becomes more puzzling when it is considered that many pricing models are used in ways in that appear to reveal very serious weaknesses. (MacKenzie and Millo, 2003; MacKenzie and Spears, 2014b).

To answer this question, the paper draws on three broad areas of academic literature: valuation models and risk management literature from mainstream finance theory; the Social Studies of Finance (SSF) and; Marxist political economy. The valuation models are examined as a tool which market participants use, a vital insight into the secluded world of derivative traders; but they are of less use when theorising the nature of derivatives or why they need such models. The SSF provide a mass of detailed observations into this secluded world, to which the author can add the experiences of almost 12 years working for a major investment bank. SSF writers also theoretically consider the interaction of human and non-human elements in financial markets including the role of valuation models in derivatives markets.

However, neither literature offers a convincing account of why todays derivatives markets require mathematical valuation models. To do so the paper uses a Marxist political economy approach, not one that enquires about derivatives' relation to the rest of capitalism or society, but rather one that makes use of a Marxist methodology to construct theoretically the logic of the internal laws of motion of derivatives markets.

Marx states that relations between objects in the capitalist economy are relations between people, in which case understanding the relation between derivatives and valuation models requires understanding the relation between derivatives market participants. [1] The paper therefore begins with derivative market participants, drawing on investigations of derivatives that use the same Marxist methodology to examine the internal relations of the derivatives markets (e.g. Lindo, 2013). In this way, the categories 'derivatives' and 'valuation models' are built in the theory from the relations between market participants. Consistent with the large trading volumes observed in these markets market participants are argued to be primarily interested in trading, by which I specifically mean buying and selling frequently to capture changes in price.[2]

The analysis becomes more complex as additional elements of the observed market are logically developed and incorporated. Thus the particular nature of today's derivatives is located in the practices of market participants, and the necessity of valuation models is located in these derivatives. Movement though the analysis is propelled by the limits and contradictions that arise at each stage as market participants establish new practices according to their incentives and constraints, and in doing so reset their environment, throwing up new limits and contradictions in the process.

Firms trading in financial markets are constrained in their trading activities by the form of securities and the necessity to deliver. Derivatives are established from trading practices where participants act *as if* they are exchanging objects without having to go to the bother of actually doing so. I provide a definition of derivatives based on the current, most developed form of derivatives, above all the cash settled derivative: derivatives are a claim between counterparts, a promise to pay money as if the counterparts had traded the underlying without them actually having to do so, and this form enables trading on a scale and scope not previously possible (Note that Marx (1993:105), discussing the Method of Political Economy, stresses the importance of studying the most developed form of a category).

However, the derivative form also imposes new constraints on market participants. First, derivatives allow differently structured claims on the same underlying which have different money prices but must be priced consistently for trading to occur, and require a translation mechanism between prices. Second, derivatives remain bilateral and un-traded claims between the two counterparts, such that large volumes of trading give rise to a mountain of bilateral promises which must be managed.

The paper analyses the Black-Scholes option model and the Gaussian Copula CDO model, and shows how together with risk management models and practices they provide market participants with solutions to both problems. First, they provide a common currency for different claims on the same underlying. This lets participants quote on potential new trades and assign prices to completed trades despite there being no actual market for them. This allows them to act *as if* the contracts are tradable, and opens the door for aggregation and risk management via statistical models (Bernstein, 1996).

The paper first briefly expands on various finance theories and their usefulness to the research question. It then turns to the emergence of derivatives. The next sections outline first, the problem of pricing multiple derivatives on the same underlying. and then how models address this problem. It then turns to the management of accumulated derivatives trades and their risk management based on models and statistical techniques.. Concluding, the paper notes the fragility that results which could be exposed by a sudden stop in trading such as in a crisis.

The usefulness of financial theories

Political economists examining the emergence of derivatives markets since the late 1980s are generally concerned with relating derivatives to broader changes in capitalism. They have located derivatives in broader regimes such as 'financial inflation' (Toporowski, 2000) or 'privatised keysiansim' (Crouch, 2009) or among broader political economy changes such as to international monetary arrangements and financial regulation (examples include Helleiner, 1994; Langley, 2002; Cerny, 1991). Similarly, political economists more strongly influenced by Marxist approaches (e.g. LiPuma and Lee, 2005; Bryan and Rafferty, 2006a; Bryan and Rafferty, 2006b; Bryan and Rafferty, 2006c; Wigan, 2008; Wigan, 2009; Norfield, 2012) have sought ‘to show how derivatives relate to the operation of a capitalist economy’ (Bryan and Rafferty, 2006a, p.39).

Unfortunately, analysis of derivatives’ place in capitalism generally does little to help explain why these markets are bound up with mathematical models. For example, Bryan and

Rafferty (2006a) are mainly concerned with derivatives' place in the broader capitalist system but never-the-less draw attention to the need to understand and incorporate the mechanics of derivatives. Their discussion of derivatives operating as capital at a third level of abstraction beyond the separation of owner and manager shares ground with the virtual nature of derivatives discussed in this paper. Yet their insight is made in order to discuss the nature of capital and derivatives capital, while the discussion of virtuality here allows us to delve into the inner workings of derivatives in order to uncover the role of models and risk management.

In short, to explain why current derivatives markets are bound up with mathematical models requires a closer look inside derivatives markets, it must focus on relations between the elements internal to the market, rather than looking outside the market to the broader context. What is needed is a political economy of financial mechanisms.

Turning to mainstream finance theory the bulk of derivatives literature (comprised largely of valuation models): 'arose (and continues to exist) primarily as an instrumentalist knowledge – how to measure financial risk, how to price options and how to trade derivatives. This seems to have virtually precluded the development of a more critical perspective within the academic tradition of finance and financial economics.' (Bryan & Rafferty, 2005, p.20)

Indeed, the valuation literature offers little insight itself into why derivatives markets and models are bound together; but the literature can be useful in a different way, namely valuation models can be examined as one of the key tools of market participants. Looking inside derivatives markets is difficult, this is a secluded world that non-participants have difficulty penetrating. The paper therefore makes a close study of valuation models and risk management literature, including their apparent flaws, as instruments that market participants use in the daily making and remaking of these markets..

The social studies of finance (SSF) literature incorporates close study of the technical apparatus that market participants use, such as valuation models, and the social arrangements that surround it. In addition, through detailed sociological / anthropological / ethnographic studies, including interviews with market participants, they provide a mass of detailed observations of the workings of derivatives trading not usually available to outsiders. The paper draws on this literature as well as the author's experience of almost twelve years working in risk control and risk management functions of a major investment bank, including transacting in derivatives, facing regulators and working extensively with the middle and back offices that process and manage completed transactions.

Theoretically SSF literature generally rejects an approach which stresses the development of new tools 'designed by talented individuals to overcome technical problems' (Engelen et al, 2008:9), although this view lingers around mainstream and official discourse regarding valuation models, not least when considering the accolades granted to Black, Scholes and Merton (e.g. Royal Swedish Academy of Sciences, 1997). Instead they consider the ways in which the human and non-human elements interact to form a whole, going as far as proposing the *assemblage* of humans, theory, tools, equipment and so on be considered the actor and not just the humans (Callon, 2005 cited in Hardie & MacKenzie, 2007). By investigating the relation between market participants and the objects they use the SSF literature correctly introduces the perspective that such objects are not independent of the making and continuous re-making of the market. So, for example, trader's screens are considered a constitutive part of a market, and not a neutral portrayer of a market that can exist without them (Knorr-Cetina & Bruegger, 2002); and desk positions and ways of communicating and calculating are critical to the form of the market which results (Beunza & Stark, 2004)

One important insight this perspective brings concerns the virtuality of derivatives markets and how virtuality is constructed. Cronon (1991:132) shows that the actual underlying to a derivative is an 'homogeneous abstraction', separated from the asset that the derivative appears to be trading. Virtuality and 'homogenous abstraction' are key elements in the definition of derivatives provided in this paper. As will be explored, derivatives are a financial instrument to trade *as if* trading in the underlying asset without actually trading it. Arnoldi, (2004, p.24) notes that 'when something comes to exist "in practice", but not in reality in the strict sense, it can be said to be *virtual*'. The social studies of finance have been particularly strong in investigating the 'material production of virtuality' (MacKenzie, 2007), including the technology, equipment and tools of the market such as valuation models.

In this SSF approach mathematical valuation models do not uncover something about derivative markets that was previously unknown, rather they contribute to defining the form and character of the markets, they are one of the conditions of its possibility (Hardie & MacKenzie, 2007) or even further 'an engine not a camera' (MacKenzie, 2006). The 'idea of economics intervening in the real world' (Latsis and Repapis, 2013, p.744) motivates researchers, led by MacKenzie and Millo (MacKenzie and Millo, 2003; MacKenzie, 2006), to ask if valuation models are performative, where performativity means that 'the issuance of the utterance is the performing of the action' (Austin, 1962, p.6), for economics, that economies perform economics.[3]

However, the impact of models on derivatives is only half the story, as MacKenzie & Spears (2014a: 394) note in a more recent paper: 'Models do indeed have effects, but – vital though that issue is – exclusive attention to their effects occludes attention to the processes that shape models and their development.' In Marxist terms performativity tends to be an idealist approach, contrasting with the materialist approach adopted in this paper. The earlier performativity studies also tend to leave market makers and other market participants 'devoid of agency and institutional surroundings'; 'traders are depicted as the "medium" … but they have no independent agency' (Engelen et al, 2008: 10).

This paper uses a Marxist methodology that draws on the evidence and insights of the valuation literature and the SSF but avoids such weaknesses, in doing so it provides an answer to the research question that other methodologies do not. By beginning with the relations between market participants it gives participants agency, what's more this agency drives the practices which form the material roots for derivatives and for valuation models. [4] Having understood the 'processes that shape models' it is better able to understand their effects.

The motivations of actors, here the profit motives of market-makers above all, lead to practices which become established and indeed indispensable. Note that these practices are not isolated behaviours but are socially established across market participants, something Ilyenkov (2012) argues is vital in the emergence of such an 'ideal'. The communicative element of valuation models is one important way amongst others in which standard practices and therefore standard models are established or embedded in the workings of dealers banks and the market in general (Mackenzie, 2003; MacKenzie and Spears, 2014b). Socially established practices take on a certain objectivity, they appear as things and impact on the development of new practices remaking and reshaping the structure within which actors 'make their own history' (Marx 1963).[5] New elements are logically incorporated into the analysis, first derivatives and then valuation models, as practices evolve in the face of fresh limits and contradictions.

Banks, financial markets and the emergence of derivatives

Analysis begins with the main participants in derivatives markets. At the heart of the derivatives markets under investigation we can observe investment banks acting as market makers. Less commonly noted than the growth of derivatives markets, is that an OTC derivative is first and foremost a transaction with a market-making bank. A relatively small group of dealer banks are one side of all OTC derivatives trades (in 2008 the BIS polled just 57 dealers to survey the whole OTC market (ISDA, 2008)). Furthermore 15-20 dealers account for the majority of this activity, for example, ISDA (2010) show that the G-14 investment banks account for over 80% of OTC notional outstanding. These dealer banks act as market-makers for derivatives in two senses: by providing liquidity, i.e. standing ready to buy and sell and making known the prices at which they are willing to do so; and by providing the market infrastructure (e.g. payment & settlement systems) (Lindo, 2013).[6] Overwhelmingly the counterparts to OTC derivatives are other financial firms, both dealers themselves and non-bank financial firms. Non-financial firms are counterpart to less than 10% of the notional outstanding (BIS, 2016).

Lindo (2013) provides a theory of banks as derivatives market makers to match this observed picture of derivatives markets as market makers. Beginning with trade credit in the circuit of production he logically builds an increasingly complex picture of banks activities to include and explain their historical emergence as derivatives dealers. Banks’s functions as first, commercial banks and then, securities dealers are explored in a manner consistent with standard Marxist analysis of banks (Marx (1976, 1981), Hilferding (1981), Lapavitsas (2003)).

He then introduces two additional factors into analysis which are critical to the current paper. First, he logically introduces institutional investors (non-bank financial firms) into the analysis. In a basic view of securities markets lending / borrowing money is inseparable from buying / selling securities at moving prices, but further analysis can separate them: individuals in such markets face an asymmetry to banks acting as market makers, mainly of scale; institutional investors overcome this by pooling the funds of lenders. In such markets banks are market makers and come to market with a price in mind to propose to other market participants.

Second, and developing largely from the introduction of institutional investors, markets are shown to be a site of trading, taken here specifically to mean buying and selling repeatedly to profit from price changes. By pooling the funds of lenders institutional investors increasingly meet liquidity requirements by matching inflows and outflows from / to lenders rather than by buying / selling securities. The original lenders are distanced from financial market activity which is increasingly carried out by asset managers of institutional investors themselves distanced from the daily liquidity requirements of lenders. The result is a market where banks and institutional investors are the dominant participants, both concerned with buying and selling repeatedly to profit from price changes and banks in particular are incentivised to trade as much and as often as possible.[7]

These conditions give rise to a new instrument especially suited to a) trading for price changes, and b) repeated trading on a large scale: the cash-settled derivative. Cash-settled derivatives are, for our purposes, the most fully developed derivative form and are taken as typical. In a cash-settled derivative counterparts pledge to pay between each other on specified dates an amount of cash which is calculated from the level of an underlying measurement or index. The archetypal cash-settled derivative is a contract for differences (CFD) where two parties promise to pay each other a sum in the future calculated from the change in an index, often based on other market prices. The payment amounts to the change in the index multiplied by a monetary amount (lexicon.ft.com). Simply put: if the index goes up I pay you, if it goes down you pay me. Note that cash-settled derivatives involve only virtual exchange, they proceed *as if* an underlying commodity-like exchange occurs but cash settlement precludes any such exchange – only cash is delivered and no commodity, security or other asset.

Cash-settled derivatives are perfectly suited to the markets characterised above. First, participants trading only for price change do not need or want to take delivery of the underlying asset be it a promise to pay or a commodity. Second, the missing underlying asset in cash-settled derivatives allows an incredible increase in the scale of derivatives trading and in the scope of things to be traded. Trading that is freed from the practicalities of delivering an underlying asset can occur in sizes and on underlying reference indices which would not otherwise be possible. Seen this way derivatives allow trade in things which cannot be otherwise traded: it is not possible to buy and sell a measurement only to buy and sell derivatives settled on that measurement. Derivatives are a trading instrument *par excellence* in markets where participants are focussed buying and selling repeatedly to capture price moves.

In short, derivatives are a claim which faces a bank acting as a market maker, the market-maker develops practices which endow this claim with properties which allow counterparts to the claim to act *as if* they are trading the underlying without actually doing so. This makes possible an enormous increase in the scale and scope of trading activities. The nature of derivatives, however, also poses problems.

The problem of pricing new trades

Further elaboration of the nature of derivatives reveals the first problem derivative pose: that of pricing potential new trades. Discussion begins with the nature of prices in these markets. In general, two categories of prices can be distinguished. First, price can describe completed exchanges, i.e. those that provided the seller with money; second, price can describe potential future prices, i.e. those in the imagination of the seller, which must be communicated to potential buyers (Marx, 1976).[8]

Particularly in a market dominated by participants trading repeatedly for price change it is vital to be able to mediate back and forth between these two types of price. In such markets it is critical to know at which price others are willing to buy and sell and the most obvious guide to this is the price at which the latest transactions occurred. Buying at a price higher than others are selling (or selling lower than others are buying) is likely to result in a loss, therefore knowing the price at which others are buying and selling is crucial 'to outwit the crowd and to pass the bad, or depreciating, half-crown to the other fellow' (Keynes, 1997, p.155).

A further complication immediately arises which heightens the importance of knowing recent market prices. In such markets 'the energies and skill of the professional investor and speculator are mainly occupied … not with making superior long-term forecasts of probable yield of an investment over its whole life, but with foreseeing change in the conventional basis of valuation a short time ahead of the general public' (Keynes, 1997, p.154-5). Famously, the activities of professional investors resemble a beauty contest where entrants must 'devote [their] intelligences to anticipating what the average opinion expects the average opinion to be' (Keynes, 1997, p.156). Traders no longer try to act on earlier fundamental information than others but rather engage in trading practices which revolve around other traders' actions.[9] As a result prices in such markets are only tenuously connected to fundamentals and can display much 'volatility and arbitrariness' (Lapavitsas, 2003).[10]

In the market for a single object the task of comparing the price of a recently completed transaction and a potential new one is trivial because the two prices, expressed in units of money, are directly comparable. In derivatives markets however the matter is more complicated. Derivatives work by being claims, but claims can be structured so that many different contracts on the same underling index are possible. First, derivatives extend trading out into the future making possible a vast number of contractual maturities; second, complex claims are possible, most obviously by introducing optionality. For example, even among simple options puts and calls with a large number of strike prices are possible. In both OTC and ETD markets the number of possible derivatives on the same underlying is very large, and in any given time period there is no practical possibility that a completed price can be observed for all of them.[11]

This vast array of instruments is troublesome because it has an equally vast array of money prices, making life complicated for market participants attempting to propose new prices consistent with those just traded. The prices of this array of instruments must be related because they are all different ways of participants acting *as if* they are buying and selling the same underlying; but even very closely related instruments can have very different money prices, e.g. a put and a call with the same expiry and the same strike will have different money prices. If traders are to avoid being passed the ‘depreciating, half-crown’ (Keynes, 1997, p.155) they must be able to price them consistently.

In earlier times this problem was circumvented because the range of instruments being traded was constrained to two, as revealed by a reverse of the pricing convention;

> On modern option exchanges, an option contract is specified with a given strike price and the price of the option (the premium) is negotiated between buyer and seller. In nineteenth century option markets, the convention was reversed. Option contracts were sold for a fixed price, but the strike price was negotiated between buyer and seller. … The fact that the strike price was the one free variable in the contract may have simplified any rules of thumb used by option sellers. (Mixon, 2009, p.176)

In other words, in nineteenth century option markets, only two instruments, one put and one call corresponding to the fixed price, were available, and the only free variable was the strike price. On modern option exchanges an array of options are available, for each maturity there are (at least) two free variables: strike and the money price of the option (even without considering more complex derivatives).

Traders must find a way to compare this vast array of potential transactions on a single underlying with each other and with recently completed trades, even as the premiums expressed in money amounts are incomparable. To make these comparisons traders use mathematical models suited to the task at hand: the standard valuation models. As the next section explores in detail the main features of these models are that they are arbitrage-free (meaning no profit can be made by simultaneous buying and selling at different prices), and they make commensurate an array of money prices by using a common pricing factor, e.g. implied volatility or implied correlation.

Valuation models and pricing potential new trades

Formalised derivative valuation models can be analysed as descendants of Black and Scholes' (1973) and Merton's (Merton, 1973; Merton, 1974) pioneering papers examining the pricing of options (hereafter 'Black & Scholes'). The basic structure of valuation models has not changed dramatically since, as is illustrated below by examination of the Black & Scholes model and the more recent one-factor Gaussian copula model. Both models are important in the development of derivatives markets: the former associated with the coming of cash settlement and the explosion of derivative trading in the 1970s and 80s (MacKenzie, 2006); the latter with the rapid build-up of securitisations in the 2000s and the subsequent financial crisis. The models have three basic elements: they define the financial instrument being priced by specifying the payments to be made between counterparts for different states of an underlying reference price index, these payments are then discounted and probability-weighted.

The key break-through of the Black & Scholes option model concerned the rate at which anticipated cash-flows should be discounted. The solution they found made their formula the grandparent of modern derivatives valuation,[12] and directly attacks the problem of comparing prices of different derivatives on the same underlying index.

Standard finance theory tells us that risk-averse investors require a risk premium (Pratt, 1964). Prior to Black & Scholes: 'the problem which had been an obstacle in the pricing of all kinds of options [was]: what risk premium should be used in the evaluation. The answer given by the Prize-Winners was: no risk premium at all!' (Royal Swedish Academy of Sciences, 1997)

Black & Scholes (1973) denote the value of an option, w, as a function of the underlying asset price, x, and time, t:

$w(x,t)$

and the sensitivity of the option value to changes in underlying asset price (the first partial derivative with respect to x) as:

$w_1(x,t)$

They construct a portfolio of one unit of underlying asset and a number of sold options, the amount determined by the hedge ratio between the two equal to:

$1/w_1(x,t)$

Such that the total sensitivity of the option positions to moves in the price of the underlying asset equals:

$w_1(x,t).-[1/w_1(x,t)]=-1$

Therefore $1/w_1(x,t)$ options combined with one unit of underlying asset produces a portfolio which is momentarily insensitive to moves in the price of the underlying. For a given asset price at a given time the portfolio is risk-free and risk preferences irrelevant: 'If risk preferences do not enter the equation, they cannot affect its solution … [allowing] … the very simple assumption that all investors are risk-neutral' (Hull, 2003, 245), therefore allowing discounting at the risk free rate.

There is however a simple logical problem with this formulation: if the option pay-off can be exactly replicated with trading in the underlying then why does the option exist? Derivatives exist on a vast scale and their existence can only be based on the *im*possibility of exactly replicating derivative pay-offs with the underlying asset. If the replicating portfolio cannot be constructed then risk neutrality, and with it the Black Scholes formula, cannot hold in its pure theoretical form. If hedging fails, even for a moment, there is a possibility of large losses on the supposedly risk-free portfolio (Haug and Taleb, 2011). Furthermore, as discussed above, at the limit derivatives exist to trade something that cannot be traded because the underlying to a derivative, even a physically settled derivative, is a 'homogeneous abstraction' such as a price index (Cronon, 1991, p.132). The impossibility of trading the underlying requires a slight adjustment to the logic of risk neutrality such that a replicating portfolio can only be comprised of derivative instruments on that underlying price index (in the simplest case one of which would satisfy $w_1(x,t) = 1$). Risk neutral pricing of derivatives should therefore be understood as comparing prices only among different derivatives.

Black Scholes gives an option price by calculating the break-even of the replicating portfolio as a result of portfolio re-hedging. Re-hedging of the portfolio is required in order to remain risk free because the second partial derivative of the option value with respect to the underlying price, $w_{11}(x,t)$, and the first derivative with respect to time, $w_1(t,x)$, are typically non-zero. Calculation of the anticipated re-hedging profits / losses is a probabilistic exercise which requires the definition of the distribution of the future price index moves.

To do so the standard Black and Scholes model uses the lognormal distribution to describe the process of the reference index price (note that use of continuous distribution requires continuous re-hedging to remain instantaneously risk free and is impossible in practice). Significantly the lognormal distribution can be described with just the first two moments of the distribution and as a result the famous Black and Scholes differential equation need go no further than the second derivative:

$$w_2 = rw - rxw_1 - \frac{1}{2} v^2x^2w_{11}$$

The inputs into the Black Scholes model can be summarised in three groups: those that form the definition of the instrument, other market parameters taken to be observable such as the risk free interest rate and, third, those for which the formula provides a solution. In the latter group are two variables, the anticipated variance and the money price of the option, which is observable for completed transactions and unobservable for potential future ones. Importantly, by choosing the lognormal distribution the price of any option on a given underlying provided by the model corresponds to a single variance number (known as volatility and given as v^2 in the formula above).

Combining the political economy of derivatives markets with the mechanics of the models it can be seen how the market participants use valuation models. The first logical step is to input observed prices of completed transactions and to obtain a single, corresponding implied volatility. In the second step the model is run in the reverse direction, the implied volatility (of the observed transaction) is input in order to calculate a consistent (but different) money price for a potential future transaction i.e. for a different derivative contract on the same underlying. The model enables market participants to translate among the vast array of possible money prices of derivatives on a given underlying, via a common implied factor, and in this way to profit from making markets (quoting prices and providing liquidity) and more generally from trading to profit from price changes.

Turning to the standard 1-factor Gaussian copula model for pricing tranches of securitisations it will be seen that the implementation of the model requires steps to be taken which allow the model to be used in the same way. Securitisations typically pool cash flows (assets) from many sources (e.g. individual mortgages, credit cards, corporate debts) and issue securities to fund their purchase. The dominant form that they came to take in the 2000s was to issue securities with an explicit credit hierarchy such that losses from the pool of assets were transmitted first to the lowest ranking security while continuing to make payments to higher ranked securities. The different ranked securities are known as tranches. The 1-factor Gaussian copula model, based mainly on a paper by Li (2000), purports to find a price for these tranches. The essential nature of the tranches reflects that of derivatives discussed above: differently structured claims on the same underlying with correspondingly incomparable money prices.

The three basic elements of the model are as discussed above: the parameters which define the cash-flows to be paid, the rate at which to discount and the probability distribution of payments. The core of the model lies in defining the probability distribution of payments from the pool of assets underlying the tranched securities. In theory the basic approach combines the expected losses of each asset to produce a loss distribution for the pool, which in turn is used to find the expected loss (and hence a price) for defined tranches. The model starts by expressing default probabilities of assets in the pool as distributions of survival times. It then combines them using a Gaussian copula (akin to combining with a correlation matrix between each asset in the pool).

To implement this approach however, the standard model makes various approximations which align the model with the imperatives discussed in the previous section: the need for a common metric to compare tranches on the same underlying which will have incomparable money prices, and a mechanism to compare potential future prices with recently observed completed market prices.

The most critical approximations to achieve the former concern the correlations used in the Gaussian copula. The first step is to make use of a latent factor to which all assets are correlated (Vasicek, 1987). This reduces the number of correlations required to n from n^2-n, (where n is the number of assets) and makes subsequent simulations easier (Hull & White, 2004, Wang et al. 2008). This advantage is however quickly superseded as the standard application of the model goes on to set all the individual asset correlations to the underlying factor to the same number. This approximation allows the model to express the price of individual tranches on the same pool not using their money prices (which are not directly comparable) but the equivalent implied correlations (which are comparable). To achieve comparability between prices of observed, completed prices and potential, future prices the model estimates the probability distribution of survival times using observed credit market prices. In the first instance this takes the credit spread (i.e. price) of each asset, however this is also superseded (where possible) with a price / credit spread for the basket as a whole.[13]

Through these approximations the model moves away from the theoretical model based on a probabilistic assessment of the underlying credit fundamentals of the portfolio to the implemented model which allows price comparison of tranches on the same underlying pool (which would otherwise have incomparable money prices) and allows these prices to be calibrated to the last observed prices for the same underlying pool of assets. Again it can be seen how the form of the standard models is shaped to meet the needs of the dominant market participants given the nature of derivatives markets.[14]

This is further emphasised when considering what appears to be a problem for the models: skew and smiles. Skew / smiles occur in both volatility and correlation markets, and occur when observed prices for different instruments on the same underlying imply different underlying probability distributions (e.g. higher implied volatility/correlation for out of the money instruments). Yet even as they seem to invalidate the models, skew/smiles are observed to be an integral and established feature of the continued use of the models (MacKenzie and Millo, 2003; MacKenzie, 2006; Mackenzie and Spears, 2014a&b). The riddle dissolves if the models are considered not as deriving prices from some fundamental analysis of the underlying probability distribution but as a quoting mechanism to compare market prices.[15]

In summary examination of the standard models shows that they are not designed to reveal a scientific truth about the nature of the market but as a tool to allow market participants to trade large volumes of derivatives. The essential nature of derivatives both enables and resists large scale trading. This section has shown that one way they resist trading is through incomparable money prices which must be compared. Models solve the problem and are therefore necessarily bound up with derivatives. The next section turns to a second way models overcome a resistance to trading that is inherent to derivatives.

Valuing and risk managing completed trades

Analysis so far has focussed on the problem of pricing a potential new transaction. Yet analysis of a single trade can only be a starting point in markets where the business of participants is repeated trading. Valuation models and risk management continuously run back and forth between large portfolios of completed contracts and prospective new transactions and analysis must therefore expand to take in this continuing transacting. This section examines valuation models as a way to assign prices to completed transactions and the ways this helps with the problems of managing existing portfolios.

As we have seen derivatives facilitate and yet resist trading by being a claim. A second way they resist is through the need to manage completed transactions. The derivative claim lets participants act *as if* they are buying and selling the underlying index, but the claim itself is rarely bought and sold, instead a second derivative transaction is added to the first, then a third, and a fourth and so on. Without further action each buy and sell adds to the stock of outstanding contracts. This contradiction is one of the most important features of derivatives: they are an un-traded claim to facilitate trading. Much of the infrastructure of markets, from the form of contracts (e.g. the ISDA Master Agreement), to the emergence of central counterparties especially since 2008, should be seen in the light of this contradiction (Lindo, 2013). Valuation models and risk-management are a critical first step in managing the vast pile of individual derivative contracts which results from large scale derivative trading.

Skilled individuals, practised in the arts of trading, can quote potential prices on a small number of derivatives positions without the aid of models. As discussed above, as derivative volumes and the number of instruments being traded grow, traders are unable to keep track of the array of money prices for different contracts on the same underlying price index and need to make use of the models. In option markets traders originally traded without aids, they then started to carry sheets containing the results of Black & Scholes calculations into the trading pits and later, and as volumes continued to grow, hand held computers (MacKenzie, 2006).

Growing overall volumes and diversity of derivative instruments increases the use of and dependency on models which moves them to centre stage. At first, the model price is seen as a deviation from real, i.e. completed, prices of derivatives transactions. As the pricing of new trades becomes increasingly reliant on the use of valuation models then model-generated prices come to appear to be *the* market price and the prices of completed transactions come to be seen as diverting from the true, or model, price. It remains completed transactions that render the seller money and constitute the liquidity that makes it possible for the model to function, yet the model (and the model price) takes on a certain objectivity.

This is reinforced by a second effect. It was seen above that the derivative claim makes pricing more complex because of the scope of possible instruments, in addition however complexity also arises because the derivative is a bilateral claim between parties with different credit worthiness, power and so on. The analysis so far, and indeed the workings of the model, leave aside the specificity of each relation and disregard differences in the prices of completed transactions due to counterparty specific elements.

Counterparty specific deviations from the model price occur to both the model's inputs and its outputs. Traders must undertake modelling to estimate the mid-price from observed prices which differ for each particular counterpart pairing (these are more pronounced in OTC markets which have more diverse counterpart pairings).[16] Similarly, traders come to market armed with the model's mid-price but trades rarely occur at mid-price, the market maker after all makes money from charging the bid-ask spread. The trader adds/subtracts from the model mid-price in order to incorporate a bid-ask spread and might also add a premium to the bid-ask for counterpart credit risk, profit margin and so on.[17]

As the model becomes central, established and objective it can be used to assign prices to completed derivative claims *as if* they could be sold – though, to repeat, they very rarely are. The model simply runs back and forth, providing common currency between completed transactions on the books of the model user and recently prices observed in the market (much as it does between potential new trades and recently observed prices). Furthermore, completed equal and opposite derivatives contracts can then be treated *as if* they exactly offset each other: the second contract can be treated *as if* it is a sale of the first.

Valuing completed trades in this way (i.e. *as if* they can be sold when in reality cannot without enormous difficulty) is a critical first step in their management and is manifested more concretely in the observable infrastructure of the markets (such as accounting practices, collateral management and regulation (Lindo, 2013, Ch.6&7)) – which only further establishes such valuation practices into the continued remaking of the markets. Note that the most common measure of derivatives markets, gross notional outstanding, is much maligned by market participants who, thanks to valuation models allowing infrastructure such as ISDA Master agreements and mark-to-market accounting, see derivatives as net and at market value. Yet without valuation models and the practices which developed from them completed derivatives do not have a market and cannot be netted. Gross notional outstanding doesn't tell us everything but it does speak to something essential about derivatives.

The assignation of a price to the un-traded derivatives is also central in allowing risk management. Valuation models can provide the current market price of a potential contract to offset each completed contract (and therefore attempt to lock in a profit or loss), but if market participants, especially dealers, had to match completed trades one-for-one with new trades, the volumes transacted would be constrained as they sought to find perfect matches. Risk-management techniques grow out of valuation models by calculating the new and offsetting trade, not on a trade-by-trade basis, but for a portfolio of trades.

The problem of defining and pricing offsetting trades for an entire portfolio is similar in nature to that of pricing a single trade; the difference now is that the quantities of completed transactions must be considered. As with the problem of price, when considering a single instrument it is possible for a trader to keep track of the net position because the quantity of contracts traded is additive. Once the scope and complexity of possible derivatives is introduced a model is required to make the positions additive. As above, this can be seen by varying maturity and by adding complexity such as optionality.

For example, a purchase of 200 million and another of 300 million in the same instrument requires an offsetting sale of 500 million. The task is harder when there are multiple instruments on the same underlying: a purchase of 200 million of a 5-year instrument and 300 million of a 2-year instrument on the same underlying cannot be offset with a sale of 500 million in either. Again the range of maturities in non-standard instruments is vast. Add optionality, e.g. a put and a call with different strikes; and it is clear that without a model the trader cannot offset these positions unless on a trade-by-trade basis.

Building on the assignation of a market value to the untraded and completed trade, valuation models also solve the problem of netting different instruments on the same underlying. Usefully they provide both prices and sensitivity to moves in the reference price index (Millo and MacKenzie, 2009); as we saw above risk-neutral pricing rests on the hedge ratio that renders the replicating portfolio risk free. Critically, these hedge ratios are additive and therefore the aggregate hedge ratio can be calculated for accumulated purchases and sales, e.g. of puts and calls on different strikes and expiries. Similarly, the hedge ratio of potential new trades can be calculated. In this way the trader can select an appropriate quantity of an instrument in order to adjust the aggregate sensitivity of his portfolio to moves in the underlying reference price index. Risk management runs back and forth between the completed portfolio and potential new trades using the hedge ratio (or sensitivities) as common currency.

The valuation produced by the derivatives models have sensitivities to other factors beside the underlying reference price index, and valuation models produce sensitivities to a variety of input parameters – known as 'Greeks' after their naming conventions (Hull, 2003). Given the nature of derivatives as future cash flows, sensitivity to interest rates and time are important examples. 'Greeks' also include sensitivity to the single organising parameter in the model, e.g. implied correlation or implied volatility. What started the analysis as a device to translate between the money prices of completed and potential prices has become in turn an index to be bought and sold, sometimes spawning new derivatives underlyings such as the Vix.[18]

By summarising the portfolio in this way the model provides the specification on a portfolio basis (and not on a trade-by-trade basis) of the new trade or trades that offset those that have gone before, or in other words that constitute the (*as-if*) sale to the original purchase (or vice versa) on a portfolio basis. The model allows risk management of the portfolio through specifying new derivatives transactions to change the risk profile of the derivatives portfolio. Now it is possible to see the inversion that occurs with the widespread establishment of derivatives trading and risk management. In the first instance it is risk management that allows the growth of derivative trading by allowing the management of large-scale trading and portfolios. With the widespread establishment of model-based derivative trading, however, it is derivative trading that allows risk management. The generalised practice of trading a large portfolio using the valuation models has bought about the objectification of risk management, and with it an inversion.

Once valuation and risk management models take on this objective character they play a vital role in the growth of these markets in other, more visible and concrete ways. They are among the practices that emerge to manage the division of labour necessary to trade derivatives on a large scale, allowing, for example, management to aggregate trading positions across several traders (MacKenzie, 2006). The growth of derivatives business in banks also required new external reporting: banks took steps to mitigate the risks of new activities and, just as importantly, needed to be seen to do this by liability holders. Risk management is used to communicate with and maintain the confidence of liability holders in a number of ways, for example, valuation at market value is the backbone of fair value accounting for financial reporting (Financial Accounting Standards Board, 2000), and modelling forms a critical component of the regulatory capital requirement, e.g. Value at

Risk (VaR) and exposure at default (EAD) calculations (Bank for International Settlements, 1996; Bank for International Settlements, 2006)). In short valuation models and risk management become embedded in and shape derivatives markets as often highlighted in the SSF literature, but an understanding of how and why this happens rests on the political economy developed here.

Conclusion

It has been shown how a political economy of derivatives markets illuminates the essential nature of derivatives as both made for and resisting the large scale and scope of trading observed in today's derivatives markets. Valuation models and risk management practices form the necessary complement to derivatives as they emerge from and tackle the obstacles to large scale trading inherent in the derivative form. Approaching derivatives in this way shows logically how the need for models arises, the practices which develop using the models, the ways in which they become embedded in the infrastructure of the markets and the way the markets develop as a result, including an inversion between the essential nature and the appearance of both prices and risk management.

The political economy approach adopted provides a logical framework to explain the derivatives markets we observe and to make use of other literature, drawing on the detailed observations of SSF writers and the structure of the valuation models themselves, as well as the author's own experience. The paper draws on SSF insights into the nature of the assemblage of human and non-human elements in derivatives markets but takes a more dialectic approach, logically developing from pricing a single new trade, to valuing existing trades to managing portfolios of trades and thereby showing valuation models as the necessary complement to derivative trading. The paper stresses the importance of tracing the material roots of the idea(l) of valuation models in order to properly understand how new practices develop, become entrenched, take on an objectivity and in doing so affect the market (Pilling, 1980; Ilyenkov, 2012).

The logical phases developed in the paper also help illustrate an inherent fragility arising from the reliance of large scale trading and valuation models and risk management practices on each other, namely that a sudden stop in trading renders the models useless and portfolios unmanageable. First, if there is no trading, there is obviously no need to produce prices for potential new trades. Second, it becomes impossible to value existing or completed (untradable) transactions by applying observed market prices. Or put another way: mark-to-market valuation of existing trades is not possible if there is no market. In this case it is impossible to assume buys and sells net. Third, hedge ratios, or Greeks, become impossible to calculate if it is not possible to calculate a valuation – indeed there is no sense in calculating the sensitivity to market price moves if there are no markets.

In short, much as Black-Scholes must be continually acted out to make it valid, the calculations of valuation models and risk management models, which make derivatives trading possible on a large scale, become meaningless if there is no on-going trading such as can happen in a crisis, and as indeed did occur in several financial markets in 2008. This self-referential fragility accords with the nature of these markets as sites for trading based not on fundamentals but as high stakes beauty contests.[19]

Valuation models and risk management are the natural complement to today's derivatives that solve the problems inherent to the derivative form and allow it to fulfil its basic function of facilitating large scale trading. They allow the pricing of potential new trades and by assigning a market price they give completed transactions they allow market participants to treat them as something that can be bought and sold. But without ongoing trading the derivative reverts to being a claim on another party settled by the underlying reference price index, and valuation must move to another basis, such as historical cost or the current level of the underlying reference price index.[20] The problem with such an approach to managing derivatives is that it is antithetical to the essence of derivatives which the political economy of derivative markets reveals: instruments that emerge to facilitate trading and which can only be differentiated from other financial instruments on this basis.

Notes

1. Marx says 'modern economists' confess 'naive astonishment when the phenomenon that they have just ponderously described as a thing reappears as a social relation and, a moment later, having been defined as a social relation, teases them once more as a thing.' (Marx, 1859, cited in Fine 1980: epigraph)

2. In a few examples: FX trading turnover averaged USD 5.3tn / day in April 2013 (BIS, 2013). OTC derivative gross notional outstanding is USD 631tn and gross market value 21tn (end 2014); just exchange traded interest rate derivatives average turnover is approximately USD5tn/day in 2014 (BIS, 2016). By way of comparison world GDP in 2014 is estimated to be 77tn/year or, assuming 365 days, USD 0.2tn / day (IMF, 2015). The WTO estimates global exports in 2014 to be USD19tn of merchandise and USD5tn of commercial services – or around USD0.07tn/day assuming 365 days (WTO, 2015). Note that these measures are not strictly comparable but never-the-less give a sense of the size of derivative markets.

3. MacKenzie (2004, p.305) says a performative utterance 'brings into being that of which it speaks'.

4. 'Everything that happens in the material world is to be explained from the material world itself' (Waddington, 1974: 23). This includes theories and mathematical models.

5. Ilyenkov (2012:158) describes the process thus: 'The *material* life-activity of social man begins to produce not only a material but also an *ideal* product, begins to produce the act of *idealisation* of reality (the process of transforming the 'material' into the 'ideal'), and then, having arisen, the 'ideal' becomes a critical component of the material life-

activity of social man, and then begins the opposite process – the process of the materialisation (objectification, reification, 'incarnation') of the ideal.'

6. Note that on exchanges (and with the rise of central counterparties (CCP) since 2008 (Trioptima, 2015)) a derivative trade is novated to face not the initial counterpart but the exchange or CCP. Never-the-less the initial counterpart remains overwhelmingly likely to be a bank and this remains the logical core of the transaction.

7. Repeated buying and selling to capture price change differs from the one-off buy/sell activities typical of the commercial sphere of commodities headed for final consumption. Participants in derivatives markets are generally both buyers and sellers, facing participants who are also buyers and sellers. In commodity markets wholesalers might be both buyers and sellers but they sell to customers who are buyers only and but from producers who are sellers only. While standardisation makes commodities alike, when headed for final consumption each commodity produced is considered separate – two chairs are not the same chair. In financial markets 'buyers, market makers, and sellers all have to share a deep conviction that the ``equivalent'' … financial instruments are really all the same.' (Carruthers and Stinchcombe, 1999:354) Traders in a given financial instrument buy and sell the 'same' thing repeatedly even when the certificate number differs. Finally buying and selling a material item differs from buying and selling virtually, as via claims in derivatives markets.

8. Discussing potential prices Marx states: 'to establish its price it is sufficient for it to be equated with gold in the imagination' (Marx, 1976, p.197) and the seller of

derivatives must ‘lend them his tongue, or hang a ticket on them, in order to communicate their prices to the outside world’ (Marx, 1976, p.189).

9. Beunza and Stark (2012) note how in such circumstances models can mediate and become critical to these interactions

10. This characterisation accords with notions of a ‘random walk’ of financial prices where tomorrow’s price cannot be predicted (Fama, 1965; Rutterford, 1993). It is however contrary to an efficient market hypothesis explanation of this random walk (Fama, 1970). It is proposed that randomness reflects a disconnection from the fundamental rather than that ‘information … is immediately reflected in stock prices’ (Malkiel, 2003)

11. On a derivatives exchange this range is finite, as the exchange effectively constrains competition in the creation of new contracts (Fehle, 2006). In OTC markets, while the central co-ordinator of an exchange, standardisation has effectively served to limit the number of plausible transactions.

12. ‘It is certainly the most important formula in derivatives’ (Camara, 2010, p.387).

13. The spread of synthetic CDO tranches based on credit indices prior to the crisis of 2007/8 was a key mechanism by which pricing via a single credit spread for the basket was established (MacKenzie & Spears, 2014a&b).

14. The use of the models appears to accord with the concept of bricolage (Engelen et al., 2008) that Dorn (2015, p.xiv) defines as ‘creative re-use of those cultural ideas and technical tools that are to hand’. Engelen et al (2012:365) state: 'This all suggests that the models are not plans or blueprints which format behaviour, but more a suite

of adaptable resources that can be drawn upon selectively to meet market opportunities that present.' Stress should be placed on '*creative* re-use' and '*adaptable* resources': standard models are not exactly the right tool for the right job, rather market participants find ways to make them useful tools in ways that are (apparently) different from their creators' intentions.

15. Similarly risk management practices appear to have failed in various crises but at the same time have become more entrenched. The riddle rests on a primary conception of risk management to prevent losses or predict crisis rather than as a tool to manage large and growing derivatives portfolios.

16. Prices expressed in the implied factor usually have the additional benefit of higher stability since the effect of other market inputs, such as interest rates or credit spreads, will have a much lower impact on the implied factor than on the final money price.

17. Calibration of the model parameters, e.g. volatility surfaces, to completed market prices is an important task for trading desks, particularly with regard to complex instruments (Benhamou, 2007). Valuation adjustments to prices and valuations have come to be labelled XVA, after Credit Valuation Adjustments (CVA) were joined by Debit Valuation Adjustments (DVA), then by Funding Valuation Adjustments (FVA) and so on. (Green, 2015)

18. As with derivatives' underlying reference price indices, it is impossible to buy implied parameters themselves; it is only possible to trade more derivatives. Initially this is via derivatives that reference the same underlying reference price index, e.g. a

portfolio of bought options on the S&P 500 will be long implied volatility – selling options on the S&P 500 will offset this sensitivity to implied volatility. In a second stage the implied volatility itself can be measured, standardised, formalised and published as an underlying price index upon which derivatives can be struck e.g. the S&P 500 Vix volatility index (Zhang, Shu and Brenner, 2010)

19. Beunza and Stark (2012, p.403) show how merger arbitrage traders use models to mediate between the observed market price and their own valuation: 'This distinctive interplay of internal [estimated by the trader] and external [derived from observed price] estimates points to a novel use of economic models, which we refer to as reflexive modelling.' Meanwhile Crouch (2009, p.394) notes 'If the only information that counts is totally reflexive and cannot be validated outside of itself, then information cannot play the role that the market needs it to play.'

20. Of course in many instances the underlying reference price index is itself calculated or modelled from market prices. In this case even this calculation may become impossible or difficult.

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