



# The next question concerning technology

## Part 1: The significance of dynamic replication

**Elie Ayache** contends that dynamic replication is the “inaugural event” of derivatives markets, and the sociologists of finance may have missed its significance

### Next technology

If I may summarize my intellectual and technical endeavor in one sentence, it will be in answer to the question: “What *next* technology for the derivatives markets?” *Technology* here embraces both the pricing engine and the “racing car” incorporating it. There is an emergency in answering the question because the current technology, as evolved as it may appear compared to the original Black-Scholes-Merton model, does not seem intended for derivatives markets. Only by accident does it – or Black-Scholes Merton, for that matter – meet with the market.

For instance, Black-Scholes-Merton assumes volatility is given and constant when, in actual fact, option traders imply it from the market prices of options. The volatility number they plug in their pricing tool is, therefore, *essentially* stochastic. Black-Scholes-Merton outputs the theoretical *value* of the given derivative instrument when, in actual fact, the market-maker deals with it as a *price*. This means the derivative instrument shall trade in a market of its own and eventually become a calibra-



tion *input*. (The situation is unchanged for more evolved smile models. The only difference is that we then calibrate, not just one, but several “volatility parameters.”)

These two principles, recalibration to market prices of derivatives and expansion of the calibration universe, amount to *flanking the theoretical model by the market*:

- Market prices as (calibration) inputs, not unobservable parameters such as volatility;
- Market prices as outputs, not theoretical values (and by that I mean that the theoretical output of the pricing model shall be recognized as a price,

therefore shall be traded).

Elsewhere, I have called these principles the *principles of irony* in derivative pricing (Ayache 2006b). “Irony” was the category supposed to stand opposite to “theory” in my dialectics. Note that the two principles can be conflated in one and simply be relabeled “the *Market Principle*.” A short statement of the *Market Principle* would then be: “From prices to prices, with technology caught in between.”

By failing to account for the market on both sides of its equation, the current technology is lacking the market altogether. And when I say this

major defect is an “emergency,” I am not only implying we should rush to repair it (otherwise I wouldn’t be calling for the *next* technology for derivatives markets, but simply for the “first,” as in “first aid”), but I also mean it in the sense of an *emergence*. Indeed, it is from out of the *current, available technology* and its very deficiency that the question of the next technology can emerge at all.

The Black-Scholes-Merton technology must come first. Otherwise, neither the model (that we wish to calibrate to the market) nor the theoretical value (that we wish to trade in the market) would even be available. By its very theoretical make-up, this first technology cannot make room for the market. All it does is carry the seeds which entail its widespread use in the market and which, as I will show, will press the question of the next technology.

Thus, the technology I am looking for will be the *first* to explicitly incorporate the market as both its premise and its purpose. Yet it will be *next* for the reason that it can only follow Black-Scholes-Merton, and that only by understanding Black-Scholes-Merton and the way it has shaped the derivatives markets can we truly pose the question of the right technology for the derivatives markets. (So in a sense, the next technology has to incorporate the conclusions of the *sociology of Black-Scholes-Merton*, or more generally, of the new field of research known as the *social studies of finance*. More on this, later.)

## Technology of the future

Elsewhere, I have called the derivatives market itself the “technology of the future” (Ayache 2006a). I did not mean it in the sense of a futuristic technology – the technology that the future is keeping for us –, but literally as the technology of the future: the technology that brings the future forth and is made of the future, in much the same way that we talk of “computer technology” or “space technology.” I have adopted this definition because the derivatives market shortcuts any claim to the *knowledge* of the future (and what is there to worry about, in the future, apart from its knowledge?) and literally “re-places” it. It reassigns it to the present of the trading floor.

By inverting the Black-Scholes formula (or any other, more sophisticated smile model) against

the market prices of derivative instruments, you infer the *market-implied volatility*. However, it would be a complete misunderstanding to go ahead and believe that the market thereby *forecasts* future volatility (and may, as a matter of fact, be proven right or wrong). The market doesn’t have *knowledge* of the stochastic process postulated by Black-Scholes-Merton or any other model. It doesn’t even so much as “stand” a representation in terms of states of the world and probability. If anything, it constantly *displaces* the current model and the current representation, by both rendering the model stochastic (through recalibration) and expanding the states of the world (through subsequent trading of the last derivative instrument that the model was supposed to value).

The market *takes place* in this dis-placing. It is everything that happens outside the representation. The trader’s *performance* (and, here, performativity is the philosophical opposite of representation) literally exceeds the model from both sides. It expresses itself in the two decisions that cannot be made part of the model, the decision to recalibrate and the decision to trade the newly priced instrument. By necessity, this performance is never in line with the model but always falls *next* to it (and I mean it both in the spatial and temporal orders: it always happens next, and it is always adjacent to the model). Therefore the trader, or the market which he embodies, cannot become an *object for probability*<sup>1</sup>. Probability consumes itself in the inner theoretical episode (the derivative pricing model) which is only a *part* of the overall technology.

Probability’s only use is to produce a (temporary) hedging ratio for the given derivative instrument or a value for another derivative instrument which will be (temporarily) non-arbitrageable with the first. Traders imply volatility from the option price in order to hedge that price or trade another option against it. Implied volatility (or any other market-implied probability distribution) serves no epistemological purpose and implies no *knowledge* of the future. All it does is re-immerses the option trader in his market as it summons him either to trade the underlying as dynamic hedging strategy or to trade another option as volatility spreading strategy. Thus the *complete* technology (comprising both the market and the pricing theory) is only ever the vehicle for achieving the *next trade*, not for

pausing and meditating upon the meaning of volatility or of the probability distribution. The derivatives market, *as technology*, thus serves a higher purpose than knowing the future. It shows the way into the future (literally making it), for there is no other way than the market.

## Technology and the social studies of finance

There seems to be total reciprocity between the question of the next technology to apply to the derivatives markets and the redefinition of the derivatives markets as the technology of the future. Both questions require that the market be brought back at the heart of the technology (and the scope of the concept of technology consequently broadened).

One recent field of research where the technology is reinstated at the heart of the market is the sociology of financial markets, also known as the *social studies of finance*. To put it in the words of one of its most prominent proponents, Donald MacKenzie: “The field brings perspectives from the social studies of science and technology to bear upon financial markets. [...] The social studies of finance addresses the *technicality* of financial markets: the role played in those markets by technologies and by systematic forms of knowledge” (MacKenzie 2006a).

The main claim of the social studies of finance is that the models of financial theory (with Black-Scholes-Merton as the paradigmatic case) and their technological applications and consequences (the algorithms and software they have produced, the risk management methodologies and regulations they have inspired) are not mere tools that help describe, or frame, or model a pre-existing reality, but that they have essentially shaped that reality and in most cases brought it in line with their own assumptions. For this reason, MacKenzie’s latest book is entitled *An Engine, Not a Camera: How Financial Models Shape Markets* (MacKenzie 2006b). Financial models are performative, argues MacKenzie, not merely representational. They literally perform and enact reality.

From my philosophical perspective, the social studies of finance are most welcome, not only because they are a form of meta-theoretical discourse like philosophy, but more specifically, because they recognize the “market” as a *different*

entity from the one that is assumed inside the theory and they thrive on the interaction between the market and technology: exactly my point. “Orthodox finance theory,” writes MacKenzie, “gives an account of markets that is in many respects perfectly successful – more successful, for instance, than any systematic rival. Where the social studies of finance departs from conventional understandings, however, is in conjecturing that at least some of finance theory’s success is performative: that finance theory succeeds because it is used by traders, regulators and others” (MacKenzie 2006a). Note that the *market* (which is here the object of investigation of the social studies of finance and which is shaped by the theory according to them: this market reality where the use of the models and the theory is accounted for and evaluated) is different from the market that orthodox theory *describes* internally. It is different from the formal stochastic process that is typically posited as ground and starting point of standard derivative pricing theory.

It may seem, at first blush, that I am only concerned with the converse question, relative to the social studies of finance. Instead of wondering how the technology shapes the market, I seem to be wondering how to reshape the technology, *now that we know* that it shall be used by traders (not by financial theorists theorizing about the market), and therefore will shape the market. Requiring, as I do above, that recalibration and the potentiality of expansion of the state space be made part of the *a priori* specifications of the next technology is indeed recognizing that market-makers, not market-spectators, will be recalibrating the pricing tool and subsequently trading the derivative instrument they have priced. (This is why the technology I am calling for looks one step beyond the conclusions of the social studies of finance, and why my agenda is to want to place the market in the technology rather than place the technology in the market. This is quite understandable, considering my technological rather than sociological inclination and the involvement of my company in derivatives technology.)

### The event-character of the market

Where I differ from the social studies of finance, however, and where my stance cannot just be

glossed at their own level as simply taking the side of the “technology” in the market/technology pair they have recognized is that it prompts a level of questioning of a totally different nature. To wit, the social studies of finance do not entail an ontological questioning of the *market* as such. They do not pose the *question of the market* as a being or as the event of its coming into being, as in: “What is the market? What happens in the market?” Although their main point is one of performativity rather than representation concerning the technology, namely, that financial models do not represent a state of affairs but literally make it happen, all that the social studies can hope to achieve is describe the mechanism allowing the technology to thus *shape* the market, not literally make it happen. They wish to describe the sociological mechanism allowing the main theoretical parameter of the Black-Scholes-Merton model, volatility, to become a common word in the market vernacular and their guess is the widespread usage of the model. They wish to describe the mechanism driving refractory market-makers to adopt the Black-Scholes-Merton model and their guess is the arbitrage pressure exerted by those who believe that the option fair value ought to be given by the cost of its replication strategy. They wish to describe the sociological mechanism allowing the Black-Scholes-Merton model to impose itself among other competing models (such as Gasteineau’s, or Kassouf’s, etc.) and their guess is the public availability of the Black-Scholes-Merton model (thanks to the option pricing sheets Black used to print daily and dispense to the floor traders as a service) and the fact that the model has managed to summarize option value in a single parameter: volatility (MacKenzie 2005).

In a word, the social studies of finance can only analyze Black-Scholes-Merton as one among many other historical, or other possible, events that may have happened to a pre-existing market. True, it may have been an event of such stature as to completely reshape a market, but it is not an *inaugural* event. In MacKenzie’s words, “the empirical success of the Black-Scholes-Merton model was a historically contingent process in which the model itself played a constitutive role” (MacKenzie 2006b 259). This suggests that a different model could have prevailed but that the performative, or self-fulfilling, power of financial models made it look, in retrospect, as if the

Black-Scholes-Merton model was, if not necessary, at least simply *true*. This effect, whereby “economic processes or their outcomes are altered so that they better correspond to the model,” MacKenzie calls “Barnesian performativity.” The reference here is to the sociologist Barry Barnes who “has emphasized the central role in social life of self-validating feedback loops” (MacKenzie 2006b 19). “‘Truth’ *did* emerge,” writes MacKenzie, “but it inhered in the process as a whole; it was not simply a case of correspondence between the model and an unaltered external reality” (MacKenzie 2006b 32).

However remarkable the fact may be that a contingent event may enforce its own truth, not to say its own world (MacKenzie speaks of “an equation and its worlds,” of an equation that “changed the world”: that “did not simply describe a pre-existing world, but helped create a world of which the theory was a truer reflection” (MacKenzie 2003)), it won’t be *inaugural* in the sense that I contend. What I call *inaugural* is an event such that we may claim, as I will be claiming later, that the market truly begins here: that the market at large, and not just the derivatives market, comes into being as a result of this event. I am not speaking of patterns of prices or of the “shape” that the ensuing market will assume. These phenomena may well be staked on a historical process such as the widespread success of Black-Scholes-Merton, and the business of the social studies of finance may well be to analyze the mechanism of change and adaptation leading to them. What I am talking about is something more originary, something the social studies of finance are not equipped to deal with, namely, the possibility that the whole *meaning* and the whole event of being of the market might be staked on such an event. This questioning is the business of philosophy.

### History and historiography

Since the advent of Black-Scholes-Merton is a contingent and historic event, according to the social studies of finance, the sociologists will naturally start looking for another example in the series of world-changing events, or simply for the next. This will be the October 1987 crash. After Black-Scholes-Merton, this is the other event having durably impacted the patterns of options prices. As MacKenzie observes, post-1987 options markets

no longer reflect classic option-pricing theory: a “volatility smile” at odds with Black-Scholes has emerged (MacKenzie 2006b 33). So the question will now become: “What *other model* have those price patterns been performing since?” This is the investigation the sociology of finance is bound to undertake next. However, such an inquiry will be fraught with difficulty. As MacKenzie explains, if an area of economics is too diverse and is changing too fast, and if different theories or models are frequently discarded and replaced (as is definitely the case with post-1987 derivative pricing technology), it will be difficult to know where to start looking in order to pin down the effects of Barnesian performativity. The good thing about Black-Scholes-Merton, writes MacKenzie, is that it was a “widely-used canonical model with decades of empirical tests” (MacKenzie 2006c).

In a way, the performative account of the sociology of Black-Scholes-Merton, to the effect that this model has truly shaped the option markets and helped creating a world which corresponded better to the theory, *is not complete* without the October 1987 crash. It is indispensable that the Black-Scholes-Merton model should eventually fail, for if this weren't the case, we might start entertaining the suspicion that the Black-Scholes-Merton model is “simply the right way to price options,” slowly acquired by market participants and by markets gradually becoming efficient. There would be no historical process to report other than this learning process and Barnesian performativity, as MacKenzie remarks, “would be an empty gloss on a process that could better be described in simpler, more conventional terms” (MacKenzie 2006b 33).

Thus the sociology of finance condemns itself to remain historical. That contingent and unconnected events happen in a market is something everybody knows; it is not an interesting phenomenon worthy of the thematic discourse of any particular science. Nor is it interesting to know, we learn from MacKenzie, that market events should, on the contrary, obey the regularity of a particular law that financial theory would, one day, know to be the truth. Not from the point of view of the sociology of finance, anyway. What is of interest for this brand of science is that processes, such as the shaping of the market by the Black-Scholes-Merton

model, may be contingent yet may offer, *at the same time*, the element of necessitation worthy of scientific theme, namely, the sociological determinism allowing a given model to enact itself and to bring the market in line with its predictions. By necessity, in order to validate the performative aspect of the given model (and reject the possibility that it may be true, *simpliciter*) the sociology of finance must consider the next contingent event that will invalidate the previous performance and shape the market differently. But by equal necessity, the sociology of finance must subsequently try to find out what new model the new patterns of prices will be performing next, and by what mechanism. For if the performative success of a given model is recognized to be a contingent historical fact, bound to cease one day, the *performativity* of models (this meta-property) is something the social studies of finance, as science, wants to ascertain and recognize as essential.

### The “first” beginning and the “other” beginning

To my mind, the advent of Black-Scholes-Merton and the October 1987 crash are joined by a much stronger link than just the fact that they follow each other in chronological order or that the first needs the second in order to ascertain its performativity as opposed to its truth and that this compels us, as a consequence, to inquire into the performance content of the second. To set in motion my philosophical thinking, the *value* of options is not the right place to start. I won't be looking for the way Black-Scholes-Merton has affected the existing price patterns or for the mechanism of that shaping. Nor will I be looking for the way option prices have deviated from the model, following the crash. Arguing for the mechanism driving the options prices in line with a model or away from the model is not arguing for the market. It is arguing for the *end* of the market – when all the prices will have converged to their theoretical values, there will be no point in the market – or for the *eternity* of the market: for the external, eternal, impenetrable fact that the market is incalculable, that it is something that will always disrupt any systematic form of knowledge and drive prices away from it. It is not arguing for the *essence* of the market. The only thing one could draw, from this external perspective, is

the historical account; and thus the inquirer would be left with the plain observation that “the empirical history of option pricing falls into three distinct phases” (as MacKenzie recognizes). He would have to observe that in the first phase, “there were substantial differences between patterns of market prices and Black-Scholes values,” that in the second, “the Black-Scholes-Merton model was an excellent fit to market prices,” and that in the third (extending from autumn 1987 to the present, notes MacKenzie), “the Black-Scholes-Merton flat-line relationship [of implied volatility across option strikes] vanished, and it has not returned” (MacKenzie 2006b 202), which is just another way of saying that we are back to the first phase.

From my philosophical reconstruction of the event and significance of Black-Scholes-Merton and of the event and significance of the October 1987 crash, it will follow that the two are joined by a nexus which will transcend the temporal order and will leave no further question as to what has been performed or what will be performed on future occasions. For, what will be performed – not by any of the two events (Black-Scholes-Merton or the 1987 crash) taken separately, but by the philosophical reflection allowing me to interpret the second through the first and, to a certain extent, the first through the second – is nothing short of the *event* of the market, or simply, the *being* of the market!

To my mind, the market truly begins with the October 1987 crash: not the historical or sociological or technical market – for that had certainly begun long before – but the *ontological* market, the market whose being and essence we can only start questioning from the moment of the October 1987 crash. Yet, in order that the market may begin, as I will contend, with the 1987 crash, I will need the seeds that were planted earlier by the Black-Scholes-Merton model and whose significance we will only start to understand *now that the market begins*. And what is this significance? Simply the way, now apparent to us in retrospect, in which this model has triggered – has literally created, not shaped – this options market whose essence we understand anew. This is why Black-Scholes-Merton is the *first beginning* and why the 1987 crash, which is where it all begins and which it would be a contradiction in terms to call the “next”

or the “second” beginning, is “another” beginning that I have no choice but to call the *other beginning* (following a terminology Heidegger uses in his later philosophy (Heidegger 1999)).

### At the beginning was dynamic replication

So what is the significance of the Black-Scholes-Merton model and how is it a beginning? How has it *created* the options markets or even, as philosophy wishes to claim, *the* market, and not merely *shaped* it or altered it or driven it in line with the theoretical values it was predicting or the worlds it was assuming, as sociology wishes to claim? To my mind, the significance of the Black-Scholes-Merton model – literally, the founding event it has produced – resides solely in the *dynamic replication* argument that the model was first to introduce. Dynamic replication is the inaugural event, not only of option value, but more importantly of options markets. Dynamic replication, I hold, is the market.

Following my proposition, Black-Scholes-Merton didn't widely succeed, as the sociology of finance claims, because it was made public when other models weren't, or because it reduced option value to a single free-parameter when other models required many parameters. It didn't enjoy universal recognition and paradigmatic status because, as MacKenzie explains, “Black and Scholes were seeking a solution to the problem of option pricing analogous to an existing exemplary solution, the Capital Asset Pricing Model,” something MacKenzie calls an “exemplar,” when somebody like Ed Thorp, who was literally using the same equation as Black-Scholes, was only “seeking market inefficiencies to exploit” (MacKenzie 2003). The only reason why Black-Scholes-Merton has succeeded and established itself as the paradigmatic model while concomitantly *establishing* the options markets is, to my mind, dynamic replication. Before Black-Scholes-Merton, all you could find in the “existing” market was, of course, heterogeneous options prices such that, if you decided to set your eyes on them and follow their history, the only interesting thing you could say about them is that a model would later come and shape them differently and bring them in line with its world. However, if you follow my proposition, you will have to admit that there is no such thing as an option market or an option value

to be shaped by Black-Scholes-Merton. There is literally nothing to find before Black-Scholes-Merton, for it is only after Black-Scholes-Merton that options *market-makers* came into existence (in a sense that I will explain shortly) and subsequently *made* the options markets.

So it is Merton, according to my re-creation, who made all the (ontological) difference, not Black and Scholes. (A difference Black and Scholes acknowledge in a footnote of their seminal article.) True, Black and Scholes differed from Thorp in that they were looking for an ideal model when he was only looking at empirical reality and for market inefficiencies. Concretely, this meant Black and Scholes believed the hedged portfolio would earn the risk-free interest rate when Thorp believed it would earn a lot more, with his own trading and return as the best living proof! (This, by the way, didn't stop Thorp from applying the same hedging strategy as prescribed by Black-Scholes and from using the risk-free interest rate in his option pricing formula on grounds of its plausibility as approximation of the expected growth of the underlying stock (MacKenzie 2006b 28-29).) Yet my claim, despite this big difference between Black-Scholes and Thorp, is that they were in an *identical* position relative to the inaugural event of options markets, namely, dynamic replication, because neither of them viewed the option hedge as the dynamic replication of the option payoff.

Let me explain.

If you compute the option value as the discounted expectation of its payoff using a discount factor appropriate to the different sorts of risk premiums involved (either of the underlying stock or of the option itself) you end up with a formula closer to Sprenkle's, or to the one Thorp ended up using, than to Black-Scholes'. In any case, the option value will, as of today, be sensitive to movements of the underlying stock and the notion of delta hedge will be available: you simply trade the underlying to cancel that Greek. However, this is no dynamic replication and for all you know, the problem may only be one-period. Full-fledged dynamic replication requires Ito's calculus and differentiation of stochastic variables. It requires integration of infinitesimal P&L variations along a ghostly stochastic path, extending from the inception of the trade to the maturity of the option.

Here, the fact that you may never know, at any point of the path, whether the next tick will be up or down, and that you should, as a consequence, always re-hedge with a lag, no matter how reactive you are or how small you make your re-hedging interval, this fact will be exactly priced in (and as) the time value of the option. This continuous infinitesimal slippage is what ultimately creates option value from the point of view of the dynamic trader, not some “static” expected value which, surely enough, would presently depend on the underlying stock price.<sup>2</sup>

Crucial to the concept of dynamic replication, and to Merton's contribution to the Black-Scholes-Merton model (or should I rather call it, the Merton model?) is, as MacKenzie notes, “the effort to replace simple ‘one-period’ models with more sophisticated ‘continuous-time’ models where not only the returns on assets vary in a continuous stochastic fashion, but individuals take decisions about portfolio selection continuously and not just at a single point in time” (MacKenzie 2003). Using the stochastic calculus brought to them by Merton and the differential expression of the hedged portfolio, Black and Scholes could then of course argue, along the lines of the CAPM, that the dynamically rebalanced portfolio is uncorrelated with the market, therefore that it must earn the risk-free rate. Merton's dynamic replication, by contrast, yields the much stronger result that “the return on the hedged position becomes certain” (“This was pointed out to us by Robert Merton,” the authors recognize in a footnote (Black and Scholes 1973)). That it should earn the risk-free rate is the direct consequence of arbitrage and is quite independent of any extrinsic reference to the market portfolio as in the CAPM.

Although it yields the same formal result as the “alternative derivation” (this is what Black and Scholes call the CAPM route in their article), Merton's dynamic replication is in fact so philosophically (even ontologically) different that the authors, even though they agreed on the equation, never agreed on its “worlds.” Merton thought a derivation based on the CAPM was “uneconomical” (in the sense of the economy of thought<sup>3</sup>) and Black and Scholes never really believed in Merton's replication. (Black feared arbitrage may be impractical because of trading costs and Scholes always worried about the feasibility of the continuous-time hedging.<sup>4</sup>)

## Vanishing ontology vs. emerging ontology

So, what is the new ontology that the event of dynamic replication has introduced? If, following Charles W. Smith, we believe that the *raison d'être* of the market – that, he says, which the market is all about – is “defining value” (Smith 2003), perhaps the value – if we can find one – that is extracted by Merton's dynamic replication can, reciprocally, help us locate and define the corresponding ontology.

Smith is the second sociologist of finance I will be considering. His work serves my purpose at this point because it goes one step beyond the sociology of finance – or one step closer to the domain of questioning proper to philosophy. What is more interesting perhaps and will help sharpen my point even better is that Smith, having thus moved, will still be missing one last turn (as you will see, it will be more of a turn-about and an inversion) to get perfectly aligned with my philosophical angle.

Smith's overall tone is more philosophical than MacKenzie's. He speaks of the ontology of options and of markets as *definitional* mechanisms. (To that extent, he moves one layer of abstraction above sociology.) He first notes that the market processes of allocation and exchange have been traditionally depicted, under the aegis of the neo-classical economic model, as governed by the principles of individual, rational self-maximization and that, in recent years, critics have challenged this view. For instance, some have recommended that the rationality and maximizing criteria be loosened (behavioral finance) and others that social and cultural embeddedness be given more attention (sociology of finance). Smith then goes on to argue that, valuable as these critiques may have been, they “continue to frame market behavior primarily as allocative in nature.” What he suggests instead is a more radical sociological critique, namely, that “many price-setting markets are primarily *definitional* processes rather than allocation processes” (Smith 2003). So, where a sociologist like MacKenzie would typically argue that the Black-Scholes-Merton model has shaped the existing options markets and turned volatility into a common word of the market vernacular, Smith, who has an eye on categories of higher order such as value or ontology, would speak of

volatility trading as “redefining value” and would throw in the balance the whole “ontological status” of options.

Specifically, Smith contends that “the Black-Scholes model has *redefined* risk in terms of the volatility of the stock rather than in terms of underlying economic factors.” By that, he means that while the value of traditional financial instruments such as stock equities or bonds is underlain by “real economic factors” (the share you purchase in an economic enterprise or the loan you make to some institution or individuals), option value is only determined by a very ethereal, volatile thing: the price process of the underlying stock. “And it becomes more complex,” he adds. Traders, he reports, quickly began to create new options clusters and strategies to take advantage of discrepancies which were now apparent between the options prices thanks to the Black-Scholes formula. Economic value, as extracted by those arbitrageurs, has therefore been redefined once again. “Where such value was and is defined primarily in terms of economic resources and moral character when discussing bonds, and in terms of economic productivity, rationality and return on capital when discussing equities, in the case of options, economic value is defined and calculated in terms of various statistical/mathematical formulas applied to past price movements of the underlying financial instruments and equities” (Smith 2003).

“Redefining market value in terms of volatility,” Smith continues, “serves to dramatically alter what can only be called the *ontological nature* of such value. Rather than reflecting [...] the material or behavioral world, value is defined in terms of an abstract mathematical model” (Smith 2003, my emphasis). Not only is the ontological nature of the value that is reflected by option prices shifting from the concrete world of economy to the abstraction of stochastic processes, but the *ontological status* of the options themselves becomes “uncertain,” Smith concludes. “Their life span can be characterized as running from nothing to nothing,” he writes. “They are created in terms of a possible future that may never be realized and are just as likely to end without ever attaining any intrinsic value” (Smith 2003).

Note that Smith speaks of the market as a definitional mechanism (it redefines value) and of the

vanishing ontological status of options when I, conversely, take the event of the options market (not just any historically or sociologically situated “market,” not a market such that the sociology of finance may investigate its shaping and reshaping, but the options market as eventuated and created by Black-Scholes-Merton, and more specifically, by the replication argument in Black-Scholes-Merton) as the ontological inception that will help us make sense of, and *redefine* the *whole category* of market. This should give you a hint about the last minute inversion – or should I say, conversion – that I said Smith was missing in order to break away completely from sociology and enter the proper domain of philosophical questioning.

### “To be” is “to be a dynamic trader”

So, to go back to our philosophical question: What is the new ontology that the event of dynamic replication has introduced? Both sociologists seem to have missed the importance of that event: the first, MacKenzie, as the way of understanding the nexus that joins the first beginning (Black-Scholes-Merton) and the other beginning (the October 1987 crash) and settles, once and for all, the question of *that* which the options prices are performing or will be performing, and the second, Smith, as the entry point into the view of option trading as an emerging – as opposed to a disappearing – ontology.

I shall say, by way of an answer, that the value that the dynamic hedger sees in the option is not staked on its intrinsic value: on whether the option ends up exercised or not, as Smith's vanishing ontology seems to suggest. The dynamic trader, seeking to track the option payoff by continuous rebalancing following Merton, generates value that is independent of whether the option is in-the-money or out-of-the-money or whether it will end up exercised or not, but depends only on the present convexity of the option (and all options are convex) and on his present capacity to *follow along* the volatility of the underlying, that is to say, on his ability to rebalance his hedge frequently enough relative to the daily decay of the option.

This practice, trading the option gamma against its theta, is the essence of the Black-Scholes-Merton equation and of volatility arbitrage. This is the breaking news option traders were introduced

to with the advent of Black-Scholes-Merton (and no other model). This is what option trading has been all about ever since, including, *and through*, the period of the 1987 crash.

I, therefore, totally agree with Smith that option market value is no longer underlain by economic realities but by the price trajectory of the underlying and, what's even worse, not even by any kind of actuality or "past prices" (as Smith says) but only by the potentiality of continuous rehedging along that trajectory, following a highly abstract mathematical algorithm. However, where Smith and I differ is that, although he has moved beyond the market embeddedness of sociological mechanisms to the appraisal of the market's higher definitional mechanisms, the conclusion he draws still occurs within sociology. It amounts to saying: "This market, now trading options of uncertain ontological status, is thus *redefining value*, sociologically speaking, and, for that matter, passing it over to abstract mathematical models." But if we leave the sociological point of view and use the replication argument as a way of penetrating inside the price trajectory and inside the minute trading of the dynamic hedger, we see new value coming out which no longer stands to be defined or redefined by an external, monumental, sociological market which we would be following through history or sociological progress, but a value that stands now *to itself* *redefine the market*. It defines it from scratch: from the minuteness of the little hedging actions taking place one after the other.

Dynamic trading, I said, is the market. Stochastic paths drawn alone in the void are certainly no market and – if that's all there is to options – will certainly make for options devoid of ontological status. But the fact that the *living trader* is now implicated in the stochastic path – the unprecedented event of his *implication by replication* – is what makes for our new definition of the market.

Thus we may lay it down. What the market (as newly defined by option trading and dynamic replication) is all about is no longer the rule of "defining value"; it is that of *breathing volatility*. This requires both volatility (the stochastic path) and someone to breathe it, to live it, and to endure it (in a continuous struggle against time decay). Since the verb "to endure," when understood intransitively, also

means "to remain in existence, to last," our new definition of the market is at the same time a definition of being-in-the-market. *To be*, for a trader, is *to endure* (to last), and "to endure" (following the theta-gamma equivalence principle brought about by Black-Scholes-Merton) can only mean "to endure volatility." The market (volatility) and the market-maker (enduring it) come together into being with the inaugural event of dynamic replication. (This ontology of dynamic trading does not even require

the option as a privileged instrument or as a vantage point; indeed, you can think of *any* dynamic trading strategy as the replication of some virtual option.)

*Ayache continues his theme in the next issue and shows how the October 1987 crash can be seen as the "other" beginning of derivatives markets. Both beginnings (the first and the other) are required in order to address the question of the next technology for derivatives markets.*

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## ENDNOTES

- [1] Contrary to Taleb's main argument in *Fooled by Randomness*.
- [2] The Greek known as "delta" (the sensitivity of the present value of the option with respect to changes in the underlying price) and the hedging ratio (the dynamic strategy ultimately

replicating the option payoff) coincide under the assumption of diffusion. However, they diverge under jumps (but then, the notion of dynamic hedging has to be reworked as *optimal* hedge).

[3] "What I sort of argued with them [Black and Scholes]," says Merton, "was, if it depended on the [capital] asset pricing model, why is it when you look at the final formula nothing about risk appears at all?" (Interviewed by MacKenzie (2006b 135); see the whole paragraph concerning Merton, in MacKenzie's book (132-138) for an illuminating discussion of the virtues of the dynamic replication argument as opposed to the much "looser" derivation via the CAPM.)

[4] Even modern derivatives experts seem to have qualms about dynamic replication. In a recent paper, Emanuel Derman and Nassim Taleb (2005) raise a charge of skepticism against dynamic replication on the usual grounds of unfeasibility of continuous hedging, of stochastic volatility, etc. As an alternative, they propose a derivation of option value based on static replication and expectation. First, they argue that option value can simply be expressed, following the "time-honoured actuarial way" as the expectation of its payoff under the appropriate discount factor and growth rate of the underlying. Second, they invoke put-call parity (in essence, a static replication argument) to conclude that the discount factor and the growth rate can only be equal to the risk-free interest rate. Thus they are able to recover the Black-Scholes-Merton formula. What surprises me from the author of *My Life As a Quant* and the author of *Dynamic Hedging* is that they both seem to have missed the fact that their derivation leaves the volatility number to stick in the formula completely undetermined. If trading the underlying dynamically against the option (dynamic replication) is not allowed, you can use *any* volatility number in your Black-Scholes-Merton formula to generate arbitrage-free and perfectly acceptable option prices, regardless of the actual volatility of the underlying. More generally, I think that anyone wishing to assess or criticize the *realism* of dynamic replication misses its significance. Dynamic replication is so important, it is so constitutive of option trading and of the trader's implication in it, that cases where it realistically fails demonstrate its validity all the better. (This, by the way, is the whole argument of my article.)