ECONOMIC MARKETS AS CALCULATIVE COLLECTIVE DEVICES

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Abstract:

How to address empirically the calculative character of markets without dissolving it? In our paper, we propose a theoretical framework that helps to deal with markets without debunking their calculative properties. In a first section, we construct a broad definition of calculation, grounded on the field of STS (science and technology studies). In the next sections, we confront this definition to three constitutive elements of markets: economic goods, economic agents and economic exchanges. First we examine the question of the calculability of goods: in order to be calculated, goods must be calculable. In the following section we introduce the notion of calculative distributed agencies to understand how these calculable goods are actually calculated. Thirdly we consider the rules and material devices that organize the encounter between (and aggregation of) individual supplies and demands, i.e. the specific organizations that allow for a calculated exchange and a market output. Those three elements define concrete markets as collective organized devices that calculate compromises on the values of goods. In each, we encounter different versions of our broad definition of calculation that we illustrate with some examples, mainly taken from the fields of financial markets and mass retail.

Markets are collective devices that allow compromises to be reached, not only on the nature of goods to produce and distribute but also on the value to be given to them.[1] The result is remarkable, considering that the original situations are often ambiguous,[2] frequently involving a large number of agents with contradictory conceptions and interests, and that the quality and characteristics of the goods are often extremely uncertain. The effectiveness of markets stems from the fact that they make complicated calculations possible, and that these produce practical solutions to problems that could not otherwise be solved by purely theoretical modelling.[3]

This calculative device is not only highly complex; it is also characterized by a wide diversity of forms of organization. Talking about the market in general is a simplification that generates more questions than answers. As an abstract reference it says nothing about the way in which goods are qualified and made comparable or different. The same applies to the tools that agents use when they calculate their choices or decisions. Likewise, very little information is provided on the organization of the encounter of these agents and on pricing procedures. It is through a concrete approach to markets (and not the market as a single abstract logic) that we can address these issues and further our understanding of the different modes of functioning of this *computandi instrumentum*. This is not an entirely new approach; it has been the subject of interesting contributions in economics and sociology. Leontief, for instance, compares the economy to 'a gigantic computing machine which tirelessly grinds out the solution of an unending stream of quantitative problems' (Leontief, 1966: 237, cited in Mirowski & Somefun, 1998). Philip Mirowski recently showed that the computing metaphor has become central in the development of economics. He proposes an analysis of market mechanisms as algorithms (Mirowski, 2002, 2003).

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[1] We wish to thank all those concerned for their feedback on the different versions of this article discussed, in particular, at the Distributed Collective Practices Conference (San Diego, February 2002), the New York Conference on the Social Studies of Finance (Columbia University, May 2002) and the Workshop on Market(ing) Practice in Shaping Markets (Stockholm, June 2003). An earlier version of this paper has been published in French (Callon & Muniesa, 2003).

[2] This is particularly visible in the case of auctions (Smith, 1989: 15-16).

[3] By presenting economic organizations in general (and not only markets) as 'compromising devices', Laurent Thévenot (2001) shows how compound arrangements have to stand up to critical tensions between different orders of worth.

If markets calculate, it should be possible to identify the entity or entities effectively responsible for the calculation, in order to answer the following simple question: Who actually calculates (and how) when we say that 'the market' calculates? Answers waver between two extreme positions. The first corresponds to the solution opted for by neo-classical economic theory: agents calculate because they are calculative by nature.[4] The second, preferred by sociology and anthropology, attempts to show that in observable behaviours, calculation, considered to be a set of quantitative practices, is marginal and at best an *ex post* rationalization for choices grounded in other logics. Neither answer is particularly satisfactory. The former fails to do justice to the diversity of practices observed and the forms of calculation applied in markets. The latter denies any particularities in economic behaviours.[5] We believe that these difficulties stem from the absence of a precise definition of the concept of calculation.[6]

In this article we consider calculation in a way that seeks to expose the elements and mechanisms allowing markets to behave as calculative collective devices. In the first section we propose a definition of calculation that oversteps the opposition between quantitative and qualitative. We then compare this definition with three conventional categories of market activity: economic goods, economic agents and economic exchange. In the second section we examine the calculability of goods: in order to be calculated, economic goods have to be calculable. The third section analyses the distributed nature of calculating agents to understand how these calculable goods are actually calculated. Finally, we consider the rules and material devices that organize the encounter between calculative agencies and calculable goods, that is, the specific organizations that make a calculated exchange possible. These three elements – calculable goods, calculative agencies and calculated exchange – define concrete markets as organized collective devices that calculate compromises on the values of goods. In each of them we encounter different versions of our definition of calculation that we illustrate with some empirical examples borrowed from financial markets and mass distribution (drawn from the literature and from our own research).

[4] See the critique by Guerrien (1999).
[5] See Cochoy (2002), for a discussion on this point.
[6] The economics of conventions (Orléan, 2004) occupies an intermediate place: it starts with the diversity of modes of calculation and recognizes the existence of calculative prostheses (norms, routines, rules) but retains the hypothesis of the key role of the individual calculative agent.

The notion of calculation re-examined

Two risks should be avoided in the definition of market calculation. The first is the risk of reverting to an abstract and formal view of economic markets governed by impersonal laws (such as the law of demand) and consisting of disembodied economic agents reduced to their preferences and calculative competencies. The second risk, more subtle and more common in sociology, consists in simply getting rid of this cumbersome notion by dissolving the problem of calculation in the detail of ethnographic description. For many anthropologists, what was supposed to be a calculative behaviour proves to be a matter of pure judgement or conjecture or, when it can be observed, something originating in institutions or cultural norms. Whereas economics maintains the idea of a reality of 'pure' calculation, the other social sciences try, by contrast, to show that real practices are infinitely more complex and leave little room for calculative practices *per se*. Whether they are studying supermarkets (e.g. Miller, 1998) or trading rooms (e.g. Knorr-Cetina & Bruegger, 2002), ethnographers tend to present actors who only rarely devote themselves to arithmetic operations in the strict sense, but who interpret information and take decisions on the basis of heterogeneous, not necessarily well-defined criteria. In the final analysis, nobody calculates (the logical outcome of considering calculation in its limited sense).

Our point of view in this article is different. Calculating does not necessarily mean performing mathematical or even numerical operations (Lave, 1988). Calculation starts by establishing distinctions between things or states of the world, and by imagining and estimating courses of action associated with things or with those states as well as their consequences. By starting with this type of definition (wide, but usual) of the notion of calculation, we try to avoid the distinction (also conventional, but too sharp) between judgement and calculation.

The validity of this position, that usefully blurs the boundary between pure judgement and pure calculation, is confirmed by etymology. In his analysis of the vocabulary of accounting and estimation in Latin sources Emile Benveniste (1993) notes that there is a close link between computing and assessing or estimating. He also points out a remarkable characteristic of this vocabulary: the explicit reference to

a material movement of detachment (cutting) and re-attachment (moving towards a result).[7]

The emphasis on the movement of material – also found in the 'centre of calculation' concept developed by Bruno Latour (1987) – helps us to formulate a very general definition of calculation as a three-step process:

- First, in order to be calculated, the entities taken into account have to be detached. A finite number of entities are moved, arranged and ordered in a single space.[8] This single space has to be conceived of in a very broad sense: it is the 'account' itself but also, by extension, the surface on which the entities to calculate are moved (literally or by delegation), then compared and manipulated on the basis of a common operating principle. It is important to take the variety of such calculative spaces into consideration. An invoice, a grid, a factory, a trading screen, a trading room, a spreadsheet, a clearinghouse, a computer memory, a trolley in a supermarket: all these spaces can be analysed as calculative spaces but all will provide different forms of calculation.

- Once they have thus been sorted out, the entities considered (taken 'into account') are associated with one another, subjected to manipulations and transformations, still in a very material sense (movements to the left or the right, up or down, superimpositions or juxtapositions). Applying a rule, in the mathematical sense, or using a mechanical calculator are obvious cases of this procedure. An economy of calculation is precisely an economy of movements, as shown by Charles Babbage in his well-known description of the bankers' clearinghouse in the City of London (Campbell-Kelly & Aspray, 1996: 15-20). But these movements are also at work in less

[7] According to Beneviste (1993, vol. I: 151-154), the two essential Latin roots of the vocabulary of 'count' are *duco* and *puto* (from the verbs *ducere* and *putare*, the latter being present in the root of the verb 'to compute'). The original meaning of *ducere* is 'to draw'. *Rationem ducere* means to lead (to conduct) a count to its total (*summa*), that is, to 'draw up' (the traditional way of adding being from the bottom up). In a more general sense (as in *'aliquid honori ducere'*), *ducere* means 'to consider something worth', but still with the idea of adding up to obtain a total. *Putare* was originally a rural term meaning to 'cut': detaching leaves from a branch as in pruning a vine, for example. Its metaphoric use for 'counting' (*rationem putare*) can be interpreted literally: 'by following the count (bottom-up), successively detaching all the articles that have been verified', that is, 'verify all the articles, one by one, to reach a valid count'.

[8] See also Latour (1987) and Bowker & Star (1999).

mechanical situations. A financial arbitrageur, for instance, materially associates two entities (an index and the corresponding derivative product, or a company and its target in the case of a potential merger) by displaying their evolution on the same computer screen (Beunza & Stark, 2004).

- A third step is necessary to obtain an accomplished calculation: a result has to be extracted. A new entity must be produced (a sum, an ordered list, an evaluation, a binary choice, etc.), which corresponds precisely to the manipulations effected in the calculative space and which, consequently, links (*summa*-rizes) the entities taken into account. This resulting entity is not new in the sense of springing from nowhere; it is prefigured by the arrangements described above. But it has to be able to leave the calculative space and circulate elsewhere in an acceptable way (without taking along all the calculative apparatus).

One of the main advantages of this definition is that, by emphasizing the crucial role of material devices without which no calculation would be possible, it inevitably points towards the diversity of possible configurations. It applies, for instance, as much to a supermarket as to a stock exchange. The order book of an electronic stock market is a calculative space (literally a computer memory) where buying and selling orders are ranked in accordance with a set of priority rules (Domowitz & Wang, 1994; Muniesa, 2003). Traders can observe the order book on their screens, explore its depth and intervene in it in several ways. The execution price is calculated by an algorithm. The results of this particular device are the prices themselves: the electronic order book is the 'black box' of what economists call 'price discovery'. A supermarket can also be considered as a calculative device (in this case prices are part of the calculative device and do not constitute the calculated result as such). The products presented are limited in number and have been removed from the context of their production and distribution. Placed in different shelves, themselves situated in different areas of the shop, they are associated with one another, grouped together or dispersed in various ways. References and markings (including prices) must enable consumers to classify the products and to make choices – that have already (partly) been calculated by the intense activity of market professionals (Barrey, Cochoy & Dubuisson-Quellier, 2000). Saying that the supermarket is a single calculative space does not mean that this space is uniform nor that the calculation is straightforward. In fact it is a space in which other calculative devices abound: packaging, shopping lists, shopping carts,[9]

[9] As a calculative space, the supermarket shopping cart is an interesting object. It is a perfect example of a device that allows products to be arranged in a single space, thus allowing several possible forms of verification and estimation. Normally, prices are not allowed in this

tills. Calculative devices can cohabit, be superimposed on one another or enter into opposition.

This definition also enables us to point out a political dimension of calculability. A similar definition of calculation allowed Peter Miller, for instance, to study the relations between calculability and government, with regard to accounting practices in particular (Miller, 1994, 2001). Isolating objects from their context, grouping them in the same frame, establishing original relations between them, classifying them and summing them up are all costly activities. The emphasis on calculative resources opens the analysis to the notion of calculative power. A calculation will be more powerful if the list of entities that it takes into account is long (yet finite); if it can process a large number of relations (between those entities) and vary those relations and their configuration; and, finally, if it provides efficient and flexible classificatory tools. The strength of a calculating agency depends on the power of the calculative tools that it mobilizes.

This definition enables us to analyse those calculative phenomena that are not 'pure'. A flaw in a calculation may be connected to a shortcoming in one (or more) of the three steps of the calculation process. For example, the list of entities to take into account is too long, no space is big enough to manipulate them together, or the manipulations require unavailable resources or cannot be performed in the timeframe imposed. The diversity of forms of operation associated with each step explains why the calculation can either meet the requirements of mathematical or algorithmic formulation, or be closer to intuition, judgement, decisions in situations of uncertainty or, finally, withdrawal. This definition establishes a continuum between qualitative judgement and quantitative (or numeric) calculation. It applies, in particular, to what Franck Cochoy calls 'qualculation', i.e. intermediate situations in which the customer has to choose certain objects placed beforehand in the same spatial and temporal frame (Cochoy, 2002). It also enables us to understand how situations of non-calculation can be constructed, for instance by preventing the closure of the list of entities to take into account, by facilitating the proliferation of relations between those entities, or by paralyzing any attempt at classification. This explains why obtaining non-calculability (i.e. the production of situations in which calculation is rendered impossible or highly complex) requires heavy investments. With this broad definition of calculation, the most appropriate dividing line is no

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space (they remain attached to the shelves), which explicitly orients the consumer's calculation towards non-arithmetic forms.

longer between judgement and calculation, but between arrangements that allow calculation (either quantitative or qualitative) and those that make it impossible.

Finally, this definition helps us to analyse and compare a calculative device and the related simulations and experiments, without changing our analytical tools. Instead of considering 'laboratory' markets, like those studied in experimental economics, as caricatures of real markets, we can explore how a particular calculative element is simulated in a particular way, and how the relationship between a market simulation in a laboratory and the actual 'scale one' market is constructed. In his study of spectrum licences auctions in the US, Francesco Guala examined the correspondences between the different versions of an economic machine that was supposed to solve a complex problem (Guala, 2001).[10] The capacities for experimentation by (or on) markets transform the conditions in which knowledge is produced on their functioning. (Theoretical) representation and (practical) intervention are closely entangled, as in the case of natural science analysed by Ian Hacking (1983).

Making goods calculable

In a market transaction a good changes hands. It is given a price, which constitutes its monetary value. The buyer, in exchange for the price paid to the seller, acquires a recognized and guaranteed right to use the good in a certain way for a certain period of time. Once the transaction has been concluded, the buyer and the seller are quits. The good is detached from the seller's world and attached to that of the buyer. That is why the market transaction has sometimes been qualified as an alienation of goods: once concluded, the transaction helps to transform the partners concerned into virtual aliens. But this image is misleading and should rather be avoided.[11] Being quits and being aliens is not exactly the same thing. The protagonists in the transaction may be quits once the transfer of ownership has been concluded, without ending all contact between each other – this is the theme of embeddedness in Granovetter's sense (Granovetter, 1985).

[10] Spectrum auctions involve complex problems. The value assigned to a frequency by a potential buyer varies, for instance, in relation to the probability of obtaining the same frequency for adjacent geographic areas.

[11] On this point see the arguments in Callon (1998), Miller (2002) and Slater (2002).

Objectification

Several comments are called for here. First, the good concerned by the transaction is not necessarily a physically delimited and tangible good such as a car or a fish. A good is a thing, in the sense that Durkheim says we must consider social facts as things. Thus, a service, even when it has no physical reality, can be the object of a market transaction if it has first been transformed into a thing.[12] A car that is available to us for certain use, under certain conditions and for a certain time (which defines property rights, in the Anglo-Saxon sense of the term), constitutes a good in the same sense as a car whose buyer is the sole owner for an indefinite period. These two goods – the rented car and the purchased car – are equally stabilized, delimited and definable. They have objective properties that allow the application and transfer of property rights.[13] Likewise, there is no difference of materiality between a fish sold on the Marseilles market and a week's skiing holiday bought by an Englishman dreaming of snow and sun. Both cases concern things that 'hold together' the elements comprising them and that can be appropriated because they have objectified properties.[14]

Second – and this point is related to the meaning of being 'quits' – the transaction does not preclude many interactions from taking place, first upstream from the actual transaction during the design and qualification of the good, and afterwards, for instance when the seller (a notion that encompasses a collective including designers, producers and salespersons) tries to grasp the reactions, comments, suggestions, complaints and demands of the consumer, with a view to taking them into account in the future.

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[12] It is in this sense that recent studies on the service economy can be understood (Gadrey, 2000).

[13] This similarity between the object-thing and the service-thing is more difficult to perceive in Roman law than in Anglo-Saxon law. For property rights in the Roman law tradition, things are supposed to be divisible between persons, whereas in Anglo-Saxon law (with the notion of a bundle of rights) things are intrinsically composite. From an anthropological point of view, this produces two different forms of proliferation of things and persons, as noted by Strathern (1999: 194).

[14] Materiality and physicality must not be confused. The anthropology of science has already illuminated this point in its analysis of the conditions of individualization and circulation of scientific facts. A thing is a black box composed of a large number of heterogeneous elements which have been folded, arranged and connected lastingly to one another and which consequently objectify the thing that they constitute (Latour, 1987).

Third, this thing that holds together because it is held by the (human and non-human) elements comprising it, is a good if and only if its properties represent a value for the buyer. This evaluation can be expressed as a price or a range of prices that the buyer is prepared to pay to appropriate the thing, that is, to become attached to it, to incorporate it into his or her world. Once he or she has acquired this good, the buyer becomes the owner. The transformation is twofold: not only is the good possessed by the owner, it also becomes part of his or her world. As Marilyn Strathern (1988) notes, by saying that A becomes the owner of vehicle V, we are referring to a market transaction, while by saying that V is a good belonging to A, we emphasize the fact that it has been incorporated into the world of A, of which it has become an integral part.

Singularization

How can we describe the process through which a thing is transformed into a good to which an economic agent assigns a value? In other words, how can we explain the integration into the buyer's world of a thing designed and produced outside of it?

The first move is to get rid of the traditional conception in which a break is postulated between human agents and the thing-goods that they conceive, produce, exchange and consume. The reality is different: it highlights the growing importance of the processes of mutual adjustment between things and human beings, consisting of multiple iterations and interactions. These can be analysed as processes of co-production of demand, supply and goods.

This process of co-production leads to a singularization of goods, an idea proposed many years ago by Chamberlin (1946) and then strangely ignored by economists and sociologists. For Chamberlin, the product is itself an economic variable that allows a singular adjustment between what the consumer (or a category of consumers) wants and what the seller offers. The process of individualization or singularization consists in a gradual definition of the properties of the product, shaped in such a way that it can enter into the consumer's world and become attached to it. Throughout the process the thing, a product undergoing qualification, is progressively transformed into a good (Callon, Méadel & Rabéharisoa, 2002). The transfer can then take place. The good leaves the world of supply, breaks away from it (which is possible since it has been objectified), and slots into another world, that of the buyer, which has been configured to receive it. It becomes entangled in the networks of socio-technical relations constituting the buyer's world.

This work of adjustment is the substance of any market transaction; only the terms change. The essential point made by Chamberlin is that, in all cases, there can be no transaction without the individualization of the product, that is, without the qualification and adjustment implied by such individualization. This position leads him to the extreme argument that advertising, the point of sale and even the salesperson's smile are not simply cosmetic contrivances used superficially and artificially at a late stage to personalize an otherwise impersonal good.[15] The famous black T Ford (for which the customer can choose the colour as long as it is black), is no exception to the rule. 'In general' a black Ford does not exist: there are only Model-T Fords, which may be black but which were individualized when the buyers decided to transform them into constituent elements of their own world.

The issue is then the obviously varied conditions and modalities of this process of singularization of products. To understand this diversity one has to bear in mind the twofold constraint weighing on a product if it is to become a good: that of objectification (it has to be a thing) and that of singularization (it has to be a thing whose properties have been adjusted to the buyer's world, if necessary by transforming that world). Objectification and singularization are produced simultaneously; objectified properties are those that allow the individualization of the good.

Co-production of properties

The properties that define the good as individual and constitute its profile or identity are neither intrinsic nor extrinsic. Two symmetrical mistakes must be avoided. The first would be to say that the characteristics of the good constitute its essence, in a sense, and are thus independent of the world in which it circulates. The second would be to say that the good is like a screen on which social representations are projected, and that its properties, reduced to significations, are given to it by consumers or society. In the first case the good is considered to be objectively describable, for example in an unquestionable list of characteristics. In the second, all possibility of objectification of the good is denied, and the multiplicity of points of view is emphasized. On the one hand, Lancaster; on the other, Baudrillard. But as soon as we agree that there can be no market transaction without a process of

[15] This argument is easy to agree with now but was by no means evident when Chamberlin formulated it in the heyday of Fordism.

objectification and singularization, the opposition dissolves. The purchase is not the result of a subject-object encounter, external to both, but of a process of attachment which, from qualification to re-qualification of the product, leads to the singularization of its properties. This does not mean that all re-qualifications are possible or that all strategies of attachment are equally probable. Properties are co-produced, which does not prevent them from being either real or singular.

The co-production of singular and objectified properties requires the involvement of a large number of 'market professionals' (marketers, packagers, designers, merchandisers, sellers, etc.) whose work is starting to be analysed and described in detail by sociologists (e.g. Barrey, Cochoy & Dubuisson-Quellier, 2000; Hennion & Méadel, 1989; Pinch, 2003; Pinch & Clark, 1995). This process of adjustment also involves a lengthy and systematic exploration of the networks of attachment constituting the buyer's (potential) world. One of the main requirements that designers and sellers have to meet is the study of buyers' attachments in order to be able to propose new ones. This work is particularly visible in the case of e-commerce.[16] Yet, as Daniel Miller (2002) notes, this exploratory work that allows the definition, objectification and individualization of the good is also important in a traditional market like the car market. Hence, there is no irreducible opposition between the practices that produce entanglement and the market transaction that implies a break.[17] The paradox is that, to achieve the transaction through which the buyer and the seller will be quits, increasingly heavy investments in the exploration of attachments and in their reconfiguration are necessary. In short, to expand the market it is necessary to produce more and more attachments. The proliferation of merchandize goes hand in hand with the proliferation of non-commercial attachments.

Singularizing a good makes it calculable

Because it has properties that objectify and singularize it, a good can be evaluated by the buyer who has been enrolled in this process of objectification-singularization. No calculation of the value of a good is possible if it has not been singularized, for its value is nothing but the force of the buyer's attachment to the good. Our definition of calculation enables us to show that the process of singularization consists in a series

[16] Techniques of identification, monitoring and analysis of Internet users' paths (e.g. in the case of a targeted marketing strategy) are a clear example.
[17] Miller does not see it but Slater (2002), commenting on Miller (2002), rightly points it out.

of operations resulting in the calculability of the good. In other words, shaping a product to transform it into a commercializable good, that is, to attach it to its buyer, amounts to making it calculable. We can easily show that these operations involve the three steps in our definition of calculation:

- The first 'logical' step in the singularization of a product, that is, its profiling, consists in establishing a space in which it can be connected and compared to a finite list of other products. In a supermarket, for example, the buyer is not required to choose a good from an infinity of goods. The shop and its material device frame this world of possible choices by drawing a boundary between the goods displayed (on the shelves) and those not taken into account. Financial markets also provide many examples of such framing. Yuval Millo and Donald MacKenzie have shown that the delimitation of the boundary between goods included in the space of market calculation and those that were excluded (because they were equated to gambling), was a key issue at the time of the introduction of financial derivatives in Chicago option markets (Millo, 2003; Mackenzie & Millo, 2003). A good becomes singularizable and thus calculable only after this operation of extraction, translation and (re)formatting.

- Singularizing a product also means linking it to other products in the same space or on the same list. This is a process of classification, clustering and sorting that makes products both comparable and different. The consumer can make choices only if the goods have been endowed with properties that produce distinctions (Cochoy, 2002). In the vocabulary of professionals of qualification, this has a name: positioning. As marketing manuals say, positioning defines consumer-targets (singularization) while defining the field of competition. Singularizing a good means endowing it with properties that make it comparable, but not identical, to other goods. Economic life is a long series of such re-qualifications or re-positionings, as in the case of a 'dietetic' product that is re-positioned as a 'health' product to conquer a broader market (Slater, 2002). This process of linking up implies, *inter alia*, the establishment of metrological networks that measure and objectify certain properties such as quality labels or, more generally, quality standards (Thévenot, 1984). The supermarket is a striking illustration of these mechanisms of assortment and re-assortment. It also highlights the fact that the singularization process is not random and that it takes into account the trajectory of products and their former qualifications, as well as the dominant classifications (e.g. the association, in France, between vinegar and oil, and between pasta and rice). In finance (an area where, as in mass distribution, this networking is particularly explicit and reflexive) we meet actors who also constantly

examine the relationship between products. Comparability and substitutability are at the heart of methods for pricing derivatives and of arbitrage techniques (Beunza & Stark, 2004; Mackenzie, 2003b). The more complex a product is, the more its marketing poses problems in terms of singularization.[18] In all cases, singularization involves this process of association, networking and positioning of products.

- The good, re-qualified, has been placed in a frame with other goods. Relations have been established between them, leading to new classifications that allow forms of comparison: the good can finally be calculated. All these operations constitute the material base of extraction of a result (a price, a classification, a choice).[19] This equivalence between the singularization of a product (that has been made comparable to other products in order to be distinguished from them) and its calculability is particularly visible in the case of complex (or 'exotic') derivatives in financial markets. The complex product, a contract drawn up by a bank for an institutional client who wants protection against particular financial risks, is reduced to a mathematical formula used to price it in relation to various elementary sub-products. The product is thus objectified and singularized: objectified because the properties qualifying it by defining it have gradually been stabilized; and singularized because these properties have been determined in such a way as to adjust it as well as possible to the client's needs. This mathematical formula generates a number that can be compared to other numbers. It is singular and comparable, and consequently calculable, but in a way that is immediate (Lépinay, 2003).

To sum up, an achieved market transaction involves a process of singularization that, by preparing the good's attachment to its buyer, makes it calculable. This applies to any market transaction but is probably even more relevant for contemporary markets characterized by an increase in investments intended to accentuate the

[18] In the case of 'exotic' derivatives, the qualification and consequently the description of the product may be highly unstable (Lépinay, 2003). They are torn between overlapping and sometimes opposing spaces of calculation within the same financial institution. The 'same' product is thus packaged in the form of a customized strategy for a particular customer (at the sales desk level), broken down into negotiable elements that can be linked to hedging strategies (at the trading desk level) and, finally, re-described in accounting terms and in settlement instructions (at the back-office level). It wavers between a high level of singularization (weak substitutability) and a high level of standardization (strong substitutability).

[19] In turn, this result produces singularization and attachment. Singularization is both the result of a calculation and the condition for new calculations.

singularization of products. The explanation can probably be found in intensified competition involving conflicts between rival singularization strategies (Callon, Méadel & Rabéharisoa, 2002), and in the development of new information and communication technologies (ICTs) and the consequent possibilities for singularization (Licoppe, 2001).

Distributed calculative agencies

The calculability of goods naturally implies the intervention of acting forces. When we talk of calculative agencies, we have in mind all the operations that make goods calculable, in the sense defined above. As we have seen, these operations involve both humans and non-humans. This leads us away from standard theories of action, that reserve agency for humans alone, towards the notion of distributed agency. Since this concept is now fairly familiar,[20] we will present it very briefly, with particular emphasis on the fact that agencies' calculative capacities are linked to their equipment, which is distributed. This characterization will enable us to consider asymmetries of calculation, a key issue in the analysis of commercial wars.

Distribution and equipment

Calculative agencies are not human individuals but collective hybrids, 'centres of calculation' (Latour, 1987). These agencies are equipped with instruments: the calculation does not take place only in human minds; it is distributed among humans and non-humans.

The notion of 'distribution' is crucial. It does not mean that flesh and blood human agents, faced with difficult calculations, use tools, without which they would never be able to accomplish their tasks. The famous thesis of Max Weber on the role of double-entry bookkeeping (DEBK) in the rise of capitalism is a clear illustration of this type of interpretation that we wish to avoid. Yamey (1949), criticizing Weber's thesis (or rather its reformulation by Sombart), affirmed, for example, that without entrepreneurship a simple bookkeeping tool could not have led to the rise of capitalism. It is not double-entry bookkeeping that calculates, he says, but the human agent, in this case the entrepreneur who decides to use it.[21] This point of view that

[20] See for instance Suchman (1987), Norman (1988), Hutchins (1995a, 1995b), and Clark (1997).
[21] On this issue see Carruthers & Espeland (1991) and Vollmer (2003).

reduces calculative tools to their instrumental dimension is common in economics, including in the less orthodox approaches (institutional, evolutionary). For Herbert Simon, it is because they are faced with complicated tasks that agents, to relieve their brains and enhance their performance, conceive of tools, create rules and routines, or set up organizations to calculate for them. By introducing these new entities (routines, rules, conventions) into the analysis, the economists who have followed Simon have unquestionably achieved a great deal: they have extended actors' cognitive capacities by redistributing their brains, at least implicitly. Studies on cognition and distributed action, as well as research in the anthropology of science and techniques (especially that based on the actor-network theory), have extended this approach by making it explicit: knowledge and action are never individual; they mobilize entities, humans and non-humans, who participate in the enterprise of knowledge or in the action.[22] This participation is active and can only exceptionally be reduced to a purely instrumental dimension.

Thus, in the case of double-entry bookkeeping, two extreme and opposite interpretations can be excluded: in the first, DEBK is a particularly efficient tool (for calculating profits) in the hands of human agents who have total control over their objectives and their actions; in the second it is an instrument of economic rationality which, simply by being used, imposes on the agents a coherence and a calculating logic that is beyond their reach (in one case it is the tool that is instrumentalized whereas in the other it is the agent). The notion of a distributed calculative agency is more demanding than this simplifying alternative.[23] It makes it possible to escape this dilemma. The entrepreneur, who is supposed to calculate his or her profits, does not use DEBK for more precise, quick and exact calculations, conceived of well before the tool itself. It is the twosome consisting of the entrepreneur and DEBK that conceives of this calculation and performs it. We could even say that DEBK, simply by being there, available, proposes this calculation to the entrepreneur who accepts the invitation and asks DEBK to do the calculation.[24]

[22] See, for instance, Latour (1996, 1999).
[23] The notion of 'calculative practices' as proposed by Peter Miller (2001) also makes it possible to avoid this instrumental view of calculation. The notion of 'calculative agency' has the advantage, in our opinion, of taking into account more clearly the variety of modes of action to which practices give substance and, in particular, the possibility of calculations with strategic aims.
[24] This idea of an invitation resonates with the notion of affordance (Gibson, 1979).

Financial markets abound with innovations, experiments and interventions that make this great variety of calculating agencies visible and thus facilitate the analysis of their constitution and functioning. Alex Preda (2003) has shown how the introduction of the stock ticker altered the equipment of traders and spawned new ways of calculating decisions in financial markets. Since prices on one or more stock exchanges could be known in real time in distant places, the development of new forms of arbitrage and speculation was encouraged. The continuous display of prices allowed the development of techniques of graphic analysis of price variations, i.e. chartism. The ticker did more than provide information: it constructed data which, owing to their format, produced specific effects of cognition and action (as shown by Jack Goody with regard to lists and tables). Likewise, the trading room of a modern investment bank produces heterogeneous forms of calculation that depend on the devices used by traders to distribute their calculative activities: trading robots, telephones, pricing tools, etc. (Beunza & Stark, 2004; Zaloom, 2003; Godechot, 2001; Knorr-Cetina & Bruegger, 2002).

Asymmetries

The activities of design, production, distribution-commercialization, prospecting, purchasing and consumption involve a large number of calculative agencies that can cooperate, compete or be independent from one another. Asymmetries are formed, and can evolve and change. We propose an analysis of these asymmetries on the basis of two criteria: a) calculative agencies can be characterized by their calculative power and b) they can have different degrees of autonomy.

1) Calculative power

As indicated above, our definition of calculation directly implies that of calculative power. A calculative agency will be all the more powerful when it is able to: a) establish a long, finite list of diverse entities; b) allow rich and varied relations between the entities thus selected, so that the space of possible classifications and re-classifications is open; and c) formalize procedures and algorithms likely to multiply the possible hierarchies and classifications between these entities.

We can easily understand that calculative power, thus defined, is unevenly distributed among the calculative agencies. Consider two explanations for this inequality: the degree of complexity and richness of the agencies' calculative devices, and the network of interconnections between them.

1.a) Richness and complexity of distributed devices

The relationship between supply and demand in a supermarket – to revert to this example – involves (at least) two calculative agencies. First, the consumer who, as we have seen, is never alone or isolated: he or she is distributed and makes assessments that involve references, brands and all sorts of pre-formatted and pre-calculated information supplied by the supermarket and its arrangements. The packaging, shelves, proximity between products, brands, labels and promotions: all of these constitute a system of distributed cognition that participates actively in the process of qualification and singularization of products. Consumers may also perform tests at home, with friends and family, and discuss the results. They read magazines and books that guide their choices. They are engaged in relations of prescription that multiply their reflection and action. At the supermarket they have a shopping list, a real cognitive prosthesis. Consumer unions organize comparative tests that turn out to be multi-criteria evaluations.[25]

But, irrespective of how strong it is, the consumer's calculative agency that evaluates the attachment of goods to his or her own world remains weak compared to the calculative power of the supply which is heavily equipped, at least in the case of a supermarket. From design right down to the positioning of the products on shelves, a series of professionals is involved, all exploring the consumer's distributed world to better integrate the product into it by playing skilfully on the product's qualification. In other words, and this point is now well documented, the difference between the calculative capacity of a child hesitating between two packets of sweets or between two pokemons, and that of a supermarket manager is not based (only) on their own calculative competencies. They are essentially the consequence of the asymmetry of equipment. For example, as Jean Lave clearly showed, the fact that a consumer does not explicitly use arithmetic when he does his shopping does not mean that he does not calculate (Lave, Murtaugh & de la Rocha, 1984). But facing him is a multitude of professionals armed with computers, studying his movements and calculating their margins down to the last cent or gram.

From this example we should not conclude that asymmetries always develop in the same direction (with supply dominating demand) or that they are final. In certain cases it is the buyer or the customer who is in a dominant calculative position, as in

[25] French economic sociology has provided a particularly interesting body of literature on these kinds of market mediations: see, for example, Barrey, Cochoy & Dubuisson-Quellier (2000), Cochoy (1999, 2002, 2004), Barrey (2001), Mallard (2000, 2002); Karpik (2000); Dubuisson-Quellier & Neuville (2003).

certain sub-contracting markets or financial situations.[26] In other cases an agency initially in an inferior position gradually acquires tools enabling it to change the balance of power and to become more active in terms of qualification and singularization. The struggle for more autonomy or recognition often involves efforts to acquire calculative equipment. The increasing role of consumer unions or user organizations, the obligation for firms to take environmental criteria into account in their own calculations, and the proliferation of freeware are examples of this type of inversion. To reverse the asymmetry between calculative powers and switch the balance of power that it implies, agencies engage in the acquisition of new calculating equipment. This changing geopolitics of calculative powers is probably more visible in finance than elsewhere. One of the typical characteristics of finance is that it makes substantial changes possible in the relative sizes of the actors involved. These changes may seem surprising if we compare them to other, more industrial forms of capitalism. As soon as they enter into the realm of high finance, stabilized forms of capital can be challenged by new actors capable of deploying calculative tactics whose impact is sometimes devastating for established interests.[27]

2.b) Connections

Another source of asymmetry between calculative powers lies in the connections that calculative agencies construct between themselves with the intention, for example, of incorporating (capitalizing on) the results of other calculative agencies. This is the case of a firm that sets up decentralized profit centres or business units, and thus delegates calculative functions to distributed agencies. It then simply incorporates and aggregates the calculations produced for it by these different units.

In consumer markets the impact of this dual movement of distribution and integration is variable but is generally more developed on the supply side than on the

[26] In certain cases a small institutional client buying a complex product from an investment bank (a fiscal optimization strategy or a contract to cover currency risks) will have no visibility of the real structure of the product and the way in which the bank prices and hedges it. In other cases, by contrast, a big client (the finance department of a multinational) will use the services of several banks (that it will play off against one another) without allowing them to understand its overall strategy. In these examples, the words 'small' and 'big' correspond not only to a question of capitalistic volume but also, more precisely, to the client's calculative power (and, even more specifically, to the size of its own trading room).

[27] We have in mind the now popular examples of the 'golden boys' who overturned the financial game in Wall Street in the '70s and '80s. See MacKenzie (2003a) for the early impact of the development of option pricing theory.

demand side. The consumer rarely has the possibility of mobilizing and controlling a large number of autonomous calculative agencies. Imagine what would happen to mass distribution if the customer standing in front of a supermarket shelf had direct access to the calculative capacities of a consumer union or to the results of laboratory tests performed at his or her request. We are nowhere near that scenario today, but the market configuration is by no means set. For instance, more and more buyers in supermarkets use their cell phones for a similar purpose (asking for someone's opinion in real time, etc.). Internet also enables consumers to mobilize various calculative agencies formerly inaccessible to them.[28]

This argument is close to those of social network analysis (e.g. proposed by Burt): the more star-shaped the connections of an agency are, the greater its calculative power is likely to be in comparison with that of other agencies to which it is connected (connection here meaning the capacity to use the calculations of others or, at least, of having access to their calculative capacities). The study of these connections, their nature and their form, enables us to raise the question of the relative autonomy of agencies: a connection can result in pure dependency if an agency is in a position to have unfettered access to another agency's calculative power.

2) Autonomy and heteronomy

Let us revert to the confrontation of calculative agencies in a supermarket. On the one hand 'the' customer calculates an attachment; on the other, 'the' seller performs a series of calculations to evaluate stocks or measure profits or market shares. We could limit the analysis to this statement and study calculative agencies in the confrontation prompting them to measure their calculative powers and, for some, finally to impose their own evaluation criteria. But the exteriority of calculative agencies, thus supposed, is simply a possible configuration that clearly fails to account for the supermarket situation. In this case, the configuration corresponds to the frequent situation in which buyers use the calculative tools that were more or less explicitly proposed to – if not imposed on – them. Of course they continue to evaluate their attachment to a good that was adjusted to their world, but they do so by means of tools designed by the seller. By inspecting shelves and reading labels, guidebooks or manuals, consumers continue a calculation started and framed by professionals of qualification. In this respect it is appropriate to remember the useful distinction between planned and impulsive buying. The former corresponds to greater autonomy for the consumer whose equipment, prepared in advance, depends less on

[28] For a clear illustration in the case of financial markets, see Lépinay & Rousseau (2000). See also the case of search engines and auction automats commented on in Mirowski (2003).

that provided by the shop. By contrast, the latter corresponds to a heteronomous position in which the consumer, strolling along without any specific intention, becomes an appendage of the calculative device created by the experts of marketing and stock.[29] A particularly striking example of the move from a position of autonomy to one of heteronomy is studied by Pierre Bourdieu in his analysis of the real estate market: the encounter between the seller and the potential buyer becomes a tug-of-war in which the former tries to impose his or her own calculative tools on the latter – often with success (Bourdieu, 2004: chapter 4). In these encounters, whether it is the consumer hesitating between two packets of smoked ham or a couple anxiously following the seller's calculations to assess their debt capacity, the confrontation is between radically different values and worlds. A particular consumer may be attached to a good that he or she finds aesthetically attractive and agree to pay the price for that attachment, whereas the seller will simply record a return on investments. When a compromise is reached it has to be interpreted as a compromise not on values but on the instruments that calculate values.

The autonomous or heteronomous relations between calculative agencies vary. An agency can change its equipment, become more powerful or decide to adopt the tools of another agency. These transformations are particularly costly and rare when heavy investments have already been made. On the other hand, when the agency has little calculative equipment, changes are more frequent and reversals of the situation more spectacular. An interesting case, from an analytical point of view, is when a supplier realizes that its calculative tools are inadequate and consequently changes them during a transaction. Such turnarounds are obviously rare in supermarkets but situations such as an inheritance would be interesting to study from this point of view, considering the variety of calculative tools that can be opted for and the hesitations of the actors concerned in choosing one of them. (For instance, how can the value of furniture that the heirs have to share be estimated? Should they rely on the established market and consult catalogues or experts to set the price of a Boulle chest of drawers or rather explore the nature and intensity of attachments: 'I know it's only worth 5,000 euros but I'm more attached to it than you because our father told me that he had me in mind when he bought it'?).

Relations between calculative agencies can be analysed by taking two dimensions into account: their relative calculative power (weak, strong) and their relative degree

[29] The same consumer may change from one type of purchase to another in the same shopping session. Recent research on e-commerce shows that the Internet consumer tends to adopt the former type of behaviour (Licoppe, Pharabod & Assadi, 2002).

of autonomy (or heteronomy). Four typical configurations are thus distinguished, and two extreme types of situation: one in which there is confrontation between two autonomous calculative agencies that calculate the same good in an entirely different way (with agreement on neither what has to be taken into account nor how to go about it), and the other in which an agency imposes its calculative tools on another agency.

A new way of conceiving of the relations of domination running through and structuring markets thus emerges, by considering that they are inscribed in relations of calculation. This point of view is not entirely new.[30] It is nevertheless increasingly difficult to conceal the power struggles behind commercial transactions when the means of calculation employed become the subject of experimentation and sometimes discussion, as in the case of financial markets and mass distribution. When they are experimented with, analysed, interpreted and evaluated, asymmetries of calculation are rendered explicit and can fuel debate.[31]

Calculated encounters

The very concept of a market is problematical because, in the general sense of the term, it implies the existence of an abstract space in which aggregated demands and supplies encounter and cross one another and, through successive adjustments, end up defining what is commonly known as the market price. In this conception the abstract market is a structure that formats (and explains) each individual commercial transaction. It is consistent with Cournot's famous definition: 'Economists understand by the term market not any particular marketplace in which things are bought and sold, but the whole region in which buyers and sellers are in such free intercourse with one another that the prices of the same goods tend to equality easily and quickly' (Cournot, 1838: 55).

For a long time this abstract conception of the market occupied a key position in economic theory, which explains why, as several authors have noted, concrete markets became invisible and were seldom studied. This conception also introduced logical and theoretical difficulties, especially when it came to explaining mechanisms

[30] See Hirschman *(1970, 1997),* for example.

[31] It would be necessary to show how asymmetries of information can be analysed as a consequence of asymmetries of calculation. This implies, in particular, that the reduction of asymmetries of information involves a reconfiguration of calculative powers.

of aggregation of supply and demand. The case of Walrasian equilibrium is an example. The problem is not only that an exceptional set of conditions has to be verified in order to produce a Walrasian type of environment (Guerrien, 1999). It is above all that neither Léon Walras nor his successors were capable of providing an appropriate description of the functioning of the mechanism of aggregation known as *'tâtonnement'* – an evocative term but one of little use from an analytical point of view.[32]

When we talk about abstract conceptions of the market, we mean precisely those approaches related to a logical explanatory principle in which concrete socio-technical devices and procedures are put aside. Referring to the market in this way is certainly depriving oneself of the explanatory key required to describe the mechanisms of aggregation and their effects. Of course, concrete markets may be designed to correspond to certain characteristics of abstract markets, as in the case of blind auction protocols (Garcia, 1986; Muniesa, 2000). But, apart from the fact that such examples are still quite rare, these markets are not 'abstracted' in the sense of mechanisms of aggregation having disappeared. On the contrary, to ensure their functioning, such mechanisms have to be very clear.

To overcome this opposition between abstract and concrete markets, we need to switch to the opposite perspective and take as a point of departure the transaction itself, that is, not the macrostructure of a hypothetical market but its 'microstructure', a particularly useful concept borrowed from economics.[33] One of the most original contributions of work on the microstructures of markets and of research in experimental economics is to have revealed the key part played by mechanisms of encountering. Without the 'explicitation' performed by researchers analysing market microstructures, and by all those who design and build them, this third element of market calculation would probably have remained in the dark. As Philip Mirowski

[32] The idea that Walrasian *tâtonnement* was empirically based on an observation of the Paris Bourse is false (Walker, 2001). But Walras never claimed that his theory was based on reality. The problem remains at the level of pure theoretical explanation: the mechanism that allows actors to calculate an exact price in a dynamic way, without trading at a 'false price', is absent from Walras' theoretical construction (Teira Serrano, 2001).

[33] The concept of a microstructure is convenient for referring to a set of transactions between a limited number of agents whose respective positions and relations depend on a particular architecture of exchange. In economics it has been proposed explicitly as a tool for studying pricing mechanisms and is used widely in the analysis of financial markets, although it is not limited to these two areas (Madhavan, 2000; Spulber, 1999).

(2003) has pointed out, this way of rendering markets explicit was stimulated by the rapid growth of new market technologies (e-commerce, automated negotiation systems in financial markets, etc.) which put the microstructures of markets to the test of R&D by systematically conducting investigations and experiments to identify and understand their mechanisms. They make explicit what we call the algorithmic configurations of the market (Muniesa, 2003).[34] This notion helps to understand how it is possible to have abstract representations of the market that can be used to act in concrete markets.

Algorithmic configurations

The use of computers in the construction of markets has changed our conception of markets. The rapid growth of e-commerce and the automation of financial markets have highlighted a fact that is well-known but seldom studied: the existence of a multiplicity of practical forms of confrontation between supply and demand. Complex double auctions (bidding for sales and purchases), Dutch auctions, bilateral structured negotiations, posted offers, and free-form bilateral discussions, among many others, clearly indicate the diversity of possible configurations.[35] The explanation of this diversity has highlighted the calculative dimension of markets and simultaneously shown that it is distinct from the calculability of products or the constitution of calculative agencies. For instance, a double auction can be described and analysed independently of the goods to which it relates and the calculative capacities of the agents involved. From this point of view, the experiments by Gode and Sunder with 'zero intelligence' traders are significant (Gode & Sunder, 1993; Mirowski & Somefun, 1998). They suggest that the convergence of traders in a double auction towards predicted prices and quantity will happen whether the traders are human subjects or dumb robots. In other words, the formulation of rules or, more exactly, algorithms that make it possible to identify the agents authorized to engage in a transaction, to describe the order in which bids and asks should be taken into consideration, and the way of matching them, are essential elements in establishing prices (what economists call 'price discovery'). Likewise, and this time in real markets, the automation of financial markets and the organization of e-commerce require a detailed definition of procedures, that is, a clarification of what Mirowski (2003) calls the market algorithm or automata.[36] The more general notion that we

[34] See also Mirowski & Somefun (1998) for a similar perspective.

[35] On the variety of possible algorithmic configurations in double auctions, see Muniesa (2003).

[36] For examples of 'explicitation' of auction mechanisms in financial markets and on the Internet, see Domowitz & Wang (1994), and Lucking-Reiley (2000).

propose is algorithmic configuration. It takes into consideration the fact that these algorithms cannot be described and defined in an abstract way, independently of the conditions and material limits of their execution.

To illustrate a concrete algorithmic configuration, take the case of the Paris Bourse and the different options envisaged and discussed in planning its automation.[37] With the introduction of automated quotation in this market, the actors were faced with a multiplicity of possible strategies and with controversies characterized by an entanglement of computing and political issues. An important choice consisted, for instance, in opting for either an order-driven market or a quote-driven market (which would embark the market on different technological and institutional tracks). In the first option, confrontation between buy and sell orders is delegated to a double auction protocol. In the second, a flesh and blood agent, the market maker, has to set the price of a share by negotiating for him- or herself and publishing his or her own range of prices. These two options, translated in different algorithmic configurations, recast the balances of power between bankers and stockbrokers differently. It was the first solution that was initially opted for with the introduction of the Canadian CATS system (Computer Assisted Trading System). But the algorithmic configurations were not transposable as such (in this case, from the Toronto Stock Exchange to the Paris Bourse) and required a process of adaptation and (socio-technical) engineering before they could be applied (Muniesa, 2004).

Another example of 'explicitation', definition and realization of the algorithmic configuration of the Paris Bourse is the introduction of a closing call auction. The call (non-continuous) auction was opted for to set closing prices. We have analysed elsewhere how this option, that involved the establishment of a complex technical apparatus, brought into play a very particular code of fairness and legitimacy in price determination (Muniesa, 2000, 2003). Other stock exchanges opted for alternative algorithmic choices for moral as much as technical reasons.

The list of elements characterizing the algorithmic configurations first rendered explicit then implemented by the Paris Bourse throughout its automation process is long and constantly changing: devices for by-passing the auction principle for high-volume orders; design of new types of orders; choice of allocation priorities; variable degree of anonymity; definition of thresholds and quotation steps; removal of round-lots, etc. This (non-exhaustive) list shows the existence of the crucial role of

[37] This example is taken from Muniesa (2003).

algorithmic configurations. They not only frame the expression of supply and demand but also determine the way in which prices are generated. This 'price discovery' is a complicated matter because it has to take into account – But how? – a large number of bids and asks that have to be linked – But how? – to one another. Instead of being reducible to two aggregated schedules that intersect at a point, or of counting on a disembodied auctioneer, 'out of reach of all control', the Paris Bourse combines different algorithmic configurations based on technical and organizational material devices, and on embodied competencies. These algorithmic configurations are real socio-technical arrangements. 'The market' does not exist independently of them.[38] Analyses of concrete and abstract markets were dissociated for a long time simply because the mechanisms of aggregation and composition of supply and demand, that these arrangements organize, were disregarded and simplified to the extreme.

Calculating and calculated algorithmic configurations

Now for a few comments on the concept of a socio-technical algorithmic configuration:

- Algorithmic configurations are calculative devices in the sense that we have given to this term. By construction they: a) circumscribe the group of calculative agencies that are to meet by making them identifiable and enumerable; b) organize their encounter, that is, their connection; and c) establish the rules or conventions that set the order in which these connections must be treated and taken into account (queues, etc.). They calculate encounters differently, depending on the way in which each of them performs these operations: each concrete market corresponds to a particular mode of organization (and calculation) of the connection between singular supplies and demands. The space of the supermarket calculates encounters. A shopping mall with its access roads, alleys, juxtaposition of shops, series of shop windows, and queues at certain points, constitutes an algorithmic configuration that, like a logical programme, organizes the encounter of calculative agencies.[39] Mailing lists, coupled with the telephone and directories to contact potential customers, are devices that can also be analysed as socio-technical algorithmic configurations (Mallard, 2002, 2004). With new ICTs, the power and diversity of encountering technologies are amplified. Nigel

[38] On this point see also the contribution from the economics of conventions, especially Favereau (1989), and Orléan (1999: 31-44).

[39] In this case prices are set and are therefore part of the qualification of goods.

Thrift (2004), who uses the notion of 'address technologies' to denote these algorithmic configurations, talks in this respect of a real qualitative break. ICTs allow physically distant and desynchronized entities to meet and constantly to renew that encounter (bar codes and SIM cards are two of the examples he gives). With these technologies, configurations become objects in their own right on which research and experimentation are done.

- These configurations of encounters do not always contribute directly to price determination. In supermarkets, for instance, prices are displayed and constitute one of the elements of the qualification of goods for sale, even if in certain cases, as in Osaka in Japan, bargaining is possible and even encouraged. In other cases, as at auctions, the algorithmic configuration plays a key part in price calculations.

- The concept of an algorithm should not be taken only in its metaphoric sense. First – and this is a lesson learned from the history and the sociology of computing – because a computer is literally an organized social space, like the market (Collins, 1990; Schaffer, 1994). Second, talking of an algorithm does justice to the idea that one or more 'logics' exist for markets and even for capitalism. An algorithm can be analysed as a logical programme. As a programme, it implies the existence of several solutions that can be attained by following a concrete set of instructions contingent on a specific situation and/or task. It can be qualified as logical in so far as it is deduced from a simple principle of action (Knuth, 1996: 59). It matches the description of the multiplicity and materiality of complex but ordered operations through which singular demands and supplies run.

- These algorithmic configurations of encounters are not existing structures in which calculative agencies simply circulate and develop. Agencies may, and often are, engaged to varying degrees in the design and negotiation of architectures that organize market encounters. An extreme situation is one in which a calculative agency almost entirely controls this 'design' work, as in the case of electronic market platforms. Financial markets offer the example of an intense struggle between the designers of market technology (conceived of as places of encounters). The architectures of the algorithmic configurations that the different stock exchanges propose to absorb the potential liquidity of markets and deprive their competitors of it are at the centre of the competition between them (Lee, 1998; Muniesa, 2003). Similar phenomena concern e-commerce sites or customer catchment areas for mass distribution. In other cases, the calculative agencies can only marginally alter the

configurations that organize their encounters since none of them are able to impose their own definition on the others.

From algorithmic configurations to abstract markets

The identification and clarification of algorithmic configurations (also called microstructures, provided that the technical dimension of material devices is included in the concept) that organize the encounter between distant and desynchronized supplies and demands raise two types of question. The first concerns the relationship between the choice of certain forms of organization of microstructures and the effects produced by those choices on the functioning of the aggregated market (and especially on price setting). The second concerns the conditions of validity of the abstract models that provide a synthetic and stylized description of the functioning of markets as calculative devices. In both cases the question of the relationship between real and abstract markets is posed.

The diversity of possible options for organizing the encounter between supply and demand inevitably raises the question of the consequences of the choice of a particular option on the function of the market as a whole. Empirical studies on the microstructure of financial markets tend to show that these effects are largely undetermined and, in any case, difficult to foresee and evaluate. There is, for example, no method for opening a trading session that can be considered as the best option applicable to all stock exchanges (Domowitz & Madhavan, 2001). The exemplary work of Alan Kirman (2001) on a very different type of market, the Marseilles fish market, enables us to take this analysis even further.[40] This study shows that there is no good reason to think that we can deduce – in any way other than statistical analysis, simulation and experimentation – the effects produced by a certain configuration of microstructures on an aggregated market. In the case of the Marseilles fish market, the aggregated market can be described as competitive whereas the various agents' behaviours are openly non-competitive. In other words, there is clearly something that can be described as an aggregated market, but its structure – if we stick to the word – is the result obtained by the economist when he or she composes a large number of singular market transactions, and not the frame defining the rules and format of those transactions. A brief reminder of Kirman's demonstration shows the importance of algorithmic configurations in the production

[40] Kirman, 2001.

of the abstract market, as well as in the analysis of relations between abstract and concrete markets.

As Kirman notes, fish markets are a traditional subject of study in economics especially because "the organization of such markets varies from location to location, for little obvious reason. In Iceland, for example, there are thirty-two auctions, eighteen of which are English ('rising price') and fourteen of which are Dutch ('descending price'). At Lorient in France, fish is sold through a combination of pairwise trading and auction, while at Sète it is sold by Dutch auction, and at nearby Marseilles by pairwise trading" (Kirman, 2001: 157). Kirman adds: "the comparison of different outcomes under different forms of organisation is an obvious research topic but one which has not received much attention to date" (ibid.: 157). From this point of view, the Marseilles market is interesting for several reasons:

- First, because very detailed data on transactions exist. In his analysis Kirman has information relative to each individual transaction (a total of 237,162) over a period of three years: the buyer's and seller's identity, the category of fish, the weight of the batch, the price of the sale, the chronological order of the transactions in each seller's day's series of transactions.

- Second, because its organization is original. On the wholesale fish market at Saumaty in Marseilles, over 500 buyers and 45 sellers come together, although they are not all present every day. Over 130 types of fish are traded. The prices are not posted and total stocks are not common knowledge at the beginning of the day. All the transactions are pairwise (that is, bilateral or over-the-counter, in financial markets' terms). There is little negotiation and the prices given by each seller can reasonably be regarded as 'take it or leave it'. The analysis of these data shows that a large proportion of buyers are loyal to their sellers. Moreover, in the same day a seller agrees to different prices for different customers, that sometimes vary widely: "successive prices charged for the same type of fish to different buyers may differ as much as 30 percent" (Kirman, 2001: 163). The distribution is stable from one day to the next, and contrary to what may be expected, during the same day no drop in price is witnessed. Paradoxically, it seems, it is the most loyal customers who are systematically charged the highest prices.

- Third, because the gap between the 'real' market and the 'abstract' market is maximal. On the real market the different behaviours do not correspond in any way to what could be expected in a competitive market. Yet the economist's calculation of

the aggregated market shows that it follows the law of demand perfectly: when the demand increases prices increase and vice-versa.

This example confirms the importance of devices that organize the expression of the supply and the demand, as well as their encounter. It is not enough to say that products are calculable (which they are since – as the buyers' loyalty to their sellers shows – goods are singularized to a very large degree). Nor is it enough to say that the agents here present are calculative agencies equipped with calculative tools (they clearly are since the buyers are also sellers who have to break even). To describe transactions it is necessary to add – and this is Kirman's contribution – that they take place in a well-defined spatial and temporal frame, that they are pairwise, with undisclosed and non-negotiated prices, that the prices set for the same category of fish by the same seller for different customers vary widely, and that encounters between buyers and sellers are regulated by powerful networks of loyalty. It is by taking into account the particular characteristics of the algorithmic configuration of the Marseilles fish market, in his simulations, that Kirman manages to explain why and how the composition of the different micro-transactions results in the constitution of a competitive aggregated market. His simulation shows two things (in particular). First, abstract markets exist and their production requires an effort in abstraction, in this case performed by an economist. Second, the description of the abstract market that sums up a particular concrete market involves the 'explicitation' of algorithmic configurations implemented by that market and by the analysis of their calculations. If the economist can talk of (abstract) markets, it is because markets can be considered as socio-technical algorithms whose shape and properties he or she analyses. Philip Mirowski's controversial argument that the legitimate objects of study of economics are economic machines and not human beings (Mirowski & Somefun, 1998; Mirowski, 2002, 2003) becomes fully meaningful when we consider 'economic machines' not as scholastic fictions but as collective calculative devices, real socio-technical configurations.

Conclusion

The purpose of this article was to render the calculative character of markets theoretically less controversial and empirically more realistic. In order to do so, we had to revise the notion of calculation, without eliminating it. Economic calculation is not an anthropological fiction, precisely because it is not a purely human mechanical and mental competence; it is distributed among human actors and material devices. As the article shows, this applies to markets. A real market can be described (at least partially) as a device for the evaluation of traded goods. This calculation is possible only if the goods can be calculated by calculative agencies whose encounters are organized by an algorithmic configuration that is stabilized to a greater or lesser degree.

This approach highlights the diversity of possible forms of organization of markets considered as devices for calculating values. A good can be made calculable, that is, individualized and objectified, in a multitude of different ways. Calculative agencies are as numerous and diverse as the tools they use and the hybrid collectives to which those tools belong. Algorithmic configurations are also multiple and diverse. These three elements (goods, agents and exchange) constitute three possible points of entry for exploring markets as complex calculative devices. Mass distribution (because it is obsessed by the singularization of products) and financial markets (because they are obsessed by processes of price setting, the configuration of calculative agencies and the organization of their encounters) are ideal examples for studying these three forms of economic calculation and the modalities of their combination.

The interpretive framework developed in this article is by no means exhaustive but we believe that it opens many avenues for research. We wish to conclude on one of its main potentialities which, in our opinion, is the capacity to renew the political questions and criticisms generated by economic markets. One of the most recurrent questions concerns the market's capacity to grasp issues concerning justice and equity, but also its propensity to destroy any form of personal relationship. Behind the variety of forms of calculation, which is the main result of our analysis, is there not a single implacable logic, one that is becoming hegemonic: that of calculation as the only possibility for action? Our approach enables us to introduce certain subtleties and nuances into the answers to this question. First, it highlights the fact that there are several ways of calculating values and reaching compromises. Second, it makes empirically observable and theoretically analysable the fact that certain agencies are exempt (or prevented, depending on the point of view) from calculation,

whereas others concentrate the most powerful calculative tools in their own hands. Third, it suggests that open discussions and even public debates on the way of organizing calculations (or on the way of excluding certain modes of calculation) are possible. In short, it restores to markets the political dimension that belongs to them and constitutes their organization as an object of debate and questioning.[41]

We also touched on the conditions in which relations can be formed between abstract and concrete markets. This could explain the increasing role of R&D and experiments in the conception of markets or in the regulation of interventions on their modes of functioning.[42] More and more actors are involved (or likely to be) in this experimental work and this investigative activity. It seems that not only social science and computing but also other stakeholders could participate as well. Note, moreover, that all the practices referred to as experimentation encompass a wide range of activities. These include laboratory work, of course (e.g. in the context of experimental economics or with the explicit aim of developing and testing algorithmic configurations), but also simulations on a large scale (e.g. when a stock exchange decides to test a computer device to assess its capacities to treat supplies and demands; the organization of focus groups or consumer tests; and the circulation of test versions in order to adjust the calculability of products). In all cases, and to varying degrees, tests are organized to clarify the functioning of the market and act on its organization. Consequently, everything that is said on technical democracy, on public discussion and on the participation of groups interested in technical controversies (Callon, Lascoumes & Barthe, 2001; Barry, 2001), applies to economics as soon as it becomes a truly experimental science.

[41] The controversial and essentially political nature of the way in which a market is constructed stems largely from the complexity and variety of aggregation methods at work. See Desrosières, 1998, and Didier, 2002, for the intrinsically political aspect of any attempt at aggregation.

[42] This point has already been discussed in Callon (1998).

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