Economics and the New Physics Some Methodological Implications

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PHYSICS PROVIDES the ideal model of scientific inquiry for the majority of economic theorists. This tendency is apparent in the writings of classical, marginalist and neo-classical economists. The main reason for this historical tendency is the alleged scientific supremacy of physics over all other scientific disciplines, and the common desire of many economists so to construct the field as to emulate the scientific status of physics.

Many economists regard nineteenth century classical physics as the ideal model of scientific methodology (Thoben, 1982; Mirowski, 1984, 1989) . The precise mechanical character of classical physics and, consequently, the predictive ability of the discipline seem the main reasons for its great scientific appeal. However, many economic theorists appear to be unaware that the scientific philosophy of modern physics has changed radically, a change that took place in the first decades of this century. The revolutionary character of the new scientific philosophy can be seen in a number of ways. For instance, the concepts of predictability and uncertainty, concepts particularly important for economics, have radically been changed. Moreover, the old problem of the relationship between the observing scientist and the objects under investigation has acquired new perspective. This revolutionary scientific methodology (associated mainly with quantum mechanics) is important for most scientific disciplines, since physics enjoys a "scientific supremacy" status for most of them.

It has also had great significance for economics. The issue of the influence of classical physics on economic thought has received attention among economists (P Mirowski's (1989a) book is a representative example.) The purpose of this paper is, first, to demonstrate that the methodology and the new physics, which has also influenced modern philosophy

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of science, is quite different from classical physics, and that this has serious implications for the scientific ideal that many economists have in their minds. Second, the paper attempts to draw some connections between the new ideas and existing approaches in economic methodology.

1. Economics and Physics

Historically, one can find abundant evidence that classical physics was the ideal model of science for a large number of economic theorists (for an extensive discussion see Mirowski, 1989a). The influence of physics can be observed even as early as the classical school. Cairnes (1875:18), for instance, explicitly supports the idea of applying methods of physical science to social phenomena. In the same spirit, marginalists like Jevons (1871:viii) see economic theory as a "close analogy to the science of Statical Mechanics". Walras compares the evolution of physics with the evolution of economics and comments that in the twentieth century "mathematical economics will rank with the mathematical sciences of astronomy and mechanics." (Walras, 1965:47-48). Edgeworth (1881:9,15), called for "mechanical explanation in the social sciences". Pareto (1986:12) and Fisher (1965:85) openly adhered to the adoption of "rational mechanics" as the model for economic science, and in an indicative example they construct a table of correspondence of mechanics and economics.

The same trend continues in the recent work of many neo-classical theorists. Samuelson, for instance, clearly believes in the application of the methodology of physics to economics and as an example he connects consumer demand with thermodynamics (Samuelson, 1966:1764 and Canterbery, 1980:179). Friedman (1984) in his well-known essay on economic methodology draws heavily from classical physics and uses its predictive success as a justification for the same method in economics. Furthermore, in the famous formulation of his monetarist theories, he compares the relation between prices and the stock of money with uniformities observed in physical sciences (Friedman 1970:67) . Von Neuman and Morgenstern's work provides another clear example. Having drawn parallels between the history of physics and economics, they maintain:

"It would be very unwise to consider anything else than the pursuit of our [economic] problems in the manner which has resulted in the establishment of physical science." (Neuman and Morgenstern, 1944:4).

Econometricians are also strong advocates of the methods of physics. The views of A. Walters can be seen as representing many theorists. Walters (1970:16-17) finds no distinction between the methodology of econometrics and the methodology of physical sciences. He is enthusiastic about the success of the physical sciences and sees them as a model which econometrics and economics in general should imitate.

Even recently, one can find explicit calls to follow physics in very influential professional economic journals. R. Solow for instance, states:

"My impression is that the best and the brightest of the profession proceed as if economics is the physics of society . . . If the project of turning economics into a hard science could succeed, then it would surely be worth doing." (Solow, 1985:330-331).

Thus, although contemporary economic theorists are not particularly keen to discuss methodological issues, it can been seen that just as many classical and marginalist economists saw physics as the scientific model, many modern theorists implicitly or explicitly still do the same.

2. Aspects of Economic Methodology

The Classical Physics Ideal

The classical physics ideal is closely connected with the gradual dominance of a Cartesian framework in orthodox economics (Positive, Modernist or Hypothetico-Deductive are other terms used, Caldwell, *1982;* Blaug, *1980).* One of the basic tenets of this methodology is that all sciences should attempt to follow the example of classical physics. The influence of the Cartesian framework, and, as we shall see, of classical physics is apparent in many methodological discussions in economics. As was noted at the outset, we shall concentrate on prediction, uncertainty and probability Some comments will be made later on the much-discussed issue of "complete detachment" or value-free analysis.

The methodology of classical physics puts much emphasis on the predictive performance of the theory. The enormous predictive power of Newton's theory of gravitation to predict the course of the planets in future periods is the main reason for this emphasis (Losee, *1980)* . Exact prediction is thought to be a clear characteristic of a hard science. One has to realize that this emphasis on prediction is based on the deterministic view of the world, which is founded on the idea that all phenomena

consist of the arrangement of atoms following mechanical, mathematically regular laws. Thus, determinism implies that a scientist can theoretically provide accurate predictions about future phenomena.

Determinism is associated with the nature of uncertainty in classical physics which is reducible. This implies that uncertainty is due to the imperfections of scientific tools, experiment, or human knowledge. This type of uncertainty can in principle be reduced if the scientist can improve the tools or experimental conditions and also through repeated experiments. Under ideal conditions classical physics was thought to be able to predict events with absolute certainty. Furthermore, the predictive ideal of classical physics is clearly apparent in the notion that physics could in principle predict the future state of the universe, if all the relevant equations were known (the Laplacean idea, Dampier, 1942).

Closely connected with the foregoing views is the idea of the complete separation of the investigating subject from the object under investigation. In classical physics there is no influence between the two. This implies that the scientist is an isolated, independent observer who, by using classical mechanics, is capable of making absolute, deterministic predictions about future phenomena.

Prediction

Many economists and econometricians (influenced also by the incorporation of this idea in the positivist philosophies of science) view prediction as the ultimate goal of scientific economics. The "predictionists" approach has become the dominant methodological viewpoint in the post war years (Coddington, *1972:8* and McCloskey, *1983).* Friedman can be seen as the main representative of this school. His methodological position is expressed in his paper "Essays in Positive Economics":

"The ultimate goal of a positive science is the development of a theory or hypothesis that yields valid and meaningful predictions about phenomena not yet observed." (Friendman, *1984:213).*

Friendman goes even further and asserts that it is irrelevant if the assumptions of a theory are false as

long as they yield meaningful predictions (Friedman, *1984:14, 23).*
Although some theorists like Samuelson *(1963)* (F-Twist), Koopmans *(1957)* and Rotwein *(1959)* reacted to this stance and some theorists like Hahn *(1984:5, 341)* have expressed reservations about the sole criterion of prediction, the majority of economists have endorsed the view that

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prediction is the goal of economic science (for an overview see McCloskey, 1983). For instance, economists like Machlup (1984), Bear and Orr (1967) followed the emphasis on prediction as the sole goal of economics. The predictionists also found considerable support among econometricians (Walters, 1970, Theil, 1971) . The inspiration of the predictionists is clearly the analogy with physical science (Stewart, 1979:86).

The majority of rational expectations theorists also follows Friedman's method in practice by explicitly stating that the purpose of theories is to generate predictions (Lucas, 1980). This instrumentalist approach seems to be gaining ground in contemporary economic methodology. This is mainly because this approach makes it easier to justify concepts which are difficult to observe (e.g. the natural rate of unemployment or maximizing behaviour).

Probability and Uncertainty in Economics

This emphasis on prediction can be associated with the dominant ideas of probability and uncertainty in economics. First, there are basically two different accounts of probability in economics. The first one sees probability as an object or property of knowledge and is usually called epistemic (Lawson, 1988). The second views probability as a property of the external reality and is called aleatory probability (Weatherford, 1982). The first type of probability is the most common in economics. Specifically, Savage (1954) and Friedman (1976) support a subjectivist or epistemic conception of probability. Moreover, Keynes uses the same approach although his conception of uncertainty is different (Lawson, 1985). The aleatory probability is not as popular, but there are some theorists like Knight (1933) who support it. There are also theorists who used both, like Muth (1961).

Related to the probability discussion are the two different approaches to uncertainty. The epistemic view of uncertainty corresponds to a situation of probabilistic knowledge (in most cases the probability is numerically measurable). This view is dominant in current neo-classical economics. In consumer theory, for example, uncertainty is connected with a subjective conception of probability. Agents are assumed to know the relevant probability distributions of all the candidate states of the world. This approach is followed by the large majority of theorists and according to Hey (1979) constitutes the basis of the economics of uncertainty.

The second type of uncertainty which corresponds to aleatory

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probability is used by some Rational Expectations proponents but who usually connect it with the agents' epistemic (subjective) probabilities (e.g. Muth). For most theorists of this school, the distributional parameters are supposed to be known and uncertainty, therefore, corresponds to a situation of numerically determinate probabilistic knowledge (Lawson, 1988).

F Knight's (1933) conception of uncertainty is also based on aleatory probabilities. But the important difference, as will be seen, is his belief that real uncertainty is unmeasurable, and he effectively suggests that all measurable uncertainty should be properly called risk. Some contemporary theorists who are more conscious of Knight's distinction between uncertainty and risk, characterize the standard orthodox conceptions of uncertainty as risk. According to many theorists, uncertainty then refers to a situation where the decision-maker is supposed not to know the probability distributions but still has a complete list of all possible states of the world (Loasby, 1976).

In general, the subject of many formulations of uncertainty in economics ". . . is to envisage a mutually exclusive and collectively exhaustive set S of candidate states-of-the world; each of these is at least logically possible, and of course one of them in fact obtains (is true)" (Balch and Fishburn, 1974:57) .

The treatment of uncertainty in econometrics is based on the aleatory approach to probability. The non-Bayesian approach to econometrics essentially incorporates uncertainty by using the error term. Usually the error term is the error of approximation. For many practicioners, the error variable has a statistical distribution (in most cases a normal or t-distribution). Even in models using a theoretical uncertainty variable, i.e. a shock or disturbance variable, its statistical treatment is such that it becomes a replica of the error model (Madansky, 1976). This approach implies that many theorists think of uncertainty as reducible in principle through better data or better variable specification.

The Bayesian approach to econometrics is basically epistemic, and once again one can find the notion of reducible uncertainty. Repeated trials always tend to reduce uncertainty, and in the ideal case, one can predict the probability of an event with absolute certainty (Geisser, 1980:17-18). In the same manner, the Bayesian approach is used to analyze uncertainty in economic theory. The standard point is that, through learning, uncertainty can be minimized (Cyert and DeGroot, 1987:4). This is related to the Rational Expectations Hypothesis: instead of assuming that market expectations lead directly to equilibrium, many theorists

assume that learning takes place in the market, and that this learning has the effect of continually modifying the prior probability distribution. Through this process the market is shown to converge to an equilibrium (Cyert and DeGroot, *1987).*

In spite of some differences in interpretation, a large majority of theorists believe that uncertainty can be reduced through the gradual accumulation of information (see for instance Radner, *1968, 1970).* This conception of uncertainty is arguably the dominant position among economists (Savage, 1954; Diamond and Rothschild, *1978;* and Lawson, 1988).

3. The Scientific Philosophy of Modern Physics

The revolution in physics in the first decades of this century introduced a new conceptual framework and a new scientific philosophy. Classical physics became just a special case and, above all, its methodology was undermined. The two physical theories which were the corpus of this revolution, were special relativity and atomic physics (quantum mechanics). Since quantum theorists are the ones who have attempted to construct a new scientific methodology and since a great number of philosophers of science have been influenced by their work, we will concentrate on microphysics.

The basic novel point underlying quantum mechanics is the under-mining of the deterministic approach of classical physics. This is achieved mainly through the introduction of irreducible uncertainty which has important implications for the idea of perfect prediction (in principle) as the sole goal of science. Moreover, the introduction of the concept of observer's influence undermines the idea of perfectly objective knowledge. Here it has to be pointed out that the founders of this methodology thought of it as having universal validity and not applicable only to microphysics (Capek, 1961).

Probability, Uncertainty and Indeterminacy in Modern Physics

The nature of probability associated with quantum mechanics is revolutionary and different from that of classical physics. For example, the probability of dice throwing with outcome 6 is compatible with the actual outcome 6. The transition from a less definite state to a more definite one is due to a change in knowledge but this transition has no implications for the actual state of the system under consideration (Feyerabend, 1964:246). In quantum mechanics, however, we have a different approach:

"Consider a measurement where possible outcomes are represented by the states ø' and ø " and which occurs when the system is in a state ø = ø ' + ø ". In this case ø cannot be regarded as an assertion to the effect that one or two mutually exclusive alternatives, ø ' and ø " occur, for when ø is realized physical processes may occur which do not occur, neither when ø ' is realized neither when ø " is realized. The transition, on measurement, from ø to, say ø ", is therefore accompanied by a change in physical conditions which does not take place in the classical sense (Feyerabend, 1964:246).

This special nature of probability is sometimes called the "interference of probabilities" (Heisenberg, 1962:157-159). This leads to the special conception of uncertainty. Apart from viewing uncertainty as inherent (aleatory), modern physicists argue that uncertainty is in principle irreducible. Going back to the dice example, the uncertainty of an outcome of dice throwing is reducible because in principle we can predict the outcome with absolute certainty (if we knew all the equations and variables involved in the dice motion, *a la* Laplace). There is not a genuine chance and thus the uncertainty involved is theoretically reducible. This is because all the variables involved are "local". In quantum mechanics these "local connections" are present too; but apart from them there are the "non-local connections" which make theoretical certainty impossible (Heisenberg, 1958:30). Heisenberg states that "the concept of probability and the attendant uncertainty enter theoretically and in principle; they do not refer merely to the theoretical errors, arising from the finiteness of, and inaccuracies in, human behaviour . . ."

(Heisenberg, 1958:16). This can be compared with the uncertainty present in thermodynamics (the favourite of Samuelson and other economists). Thermodynamics had a statistical or probabilistic nature but the molecules of gasses were still assumed to interact in a deterministic way according to classical laws. The uncertainty in this theory arose because of the large number of molecules and the *difficulty in* calculating their individual movement. In spite of the practical difficulties in calculation, the uncertainty present in thermodynamics is in theory reducible.

The special character of probability and uncertainty is also shown by the fact that a number of physicists, in order to distinguish the uncertainty associated with this sort of probability from the usual conception, have called it indeterminacy (Bohm, 1957) . It is also clear that the concept of irreducible uncertainty is the main point of departure from classical physics. Furthermore, it undermines determinism since, as we

shall see, it implies ineliminable unpredictability (Bohr, 1965 and Heisenberg, 1958).

The idea of indeterminacy in physics is clearly shown through the basic formula in quantum mechanics. If we define Ä*x* as the indefiniteness of the position of an electron and Ä*px* the indefiniteness of the momentum, and *h* as Plank's constant, (Giancoli, 1984:798) we have

D*xpx* > *h/2*p

The uncertainty involved cannot be smaller than a certain number (irreducible). In particular, as the indeterminacy of position is reduced, the indeterminacy of momentum is increasing. Other formulations of the indeterminacy relations include energy and time, angular momentum and angular position. The above imply that uncertainty is aleatory and irreducible (Feyerabend, 1964:202 and Giancoli, 1984:798-790). This idea has been formulated in more general terms as Bohr's complementarity principle which refers to magnitudes where the measurement of one prevents the accurate simultaneous measurement of the other. This can be extended to concepts: two concepts are complementary when one imposes limitations on the other (Segre, 1980:167).

Prediction in Modern Physics

The previous discussion on the nature of uncertainty and probability has implications for the emphasis placed on prediction by classical physics. Since uncertainty is pervasive, *the idea of prediction as the sole goal of science is clearly undermined.* An example might illustrate the point. An experiment is performed in order to find out the amount of energy of the hydrogen atom and the result is *3.40ev* (electro-volts). If the same experiment is performed again under the same conditions, it is unlikely that the same value will be found. It is impossible to know the result of the second experiment before performing it because of aleatory and also irreducible uncertainty. The only thing that we can estimate is the probability of finding the initial value *3.40ev.* In the context of the classical physics the only result possible, assuming identical conditions, will be the initial one (allowing for small errors due to experimental apparatus and measurement) (Tambakis, 1984:69, and Giancoli, 1984:799).

Arguments against prediction as the most important characteristic of science have been put forward by theorists like Eddington (1964) and Bohr (1965). Bohr, especially, in his Nobel lecture states that:

"The most that one can demand of a theory is that this classification

can be pushed so far that it can contribute to the development of the field of observation by the prediction of new phenomena. When we consider the atomic theory, we are, however, in the peculiar position that there can be no question of an explanation in this last sense." (Bohr, 1965:43).

It has to be pointed out that uncertainty and unpredictability are not special characteristics of atomic physics. In theory, they also hold in the macroscopic level, or in other words, the formulations of the theory are not confined to microscopic phenomena but are general. For instance, Heisenberg's uncertainty principle is still valid when it comes to the momentum and the position of a bullet travelling on a horizontal course. Apart from the very small irreducible uncertainty in its momentum and position, there is an extremely small but finite probability that it will curve up. Thus, in principle, even the behaviour of ordinary objects can be predicted probabilistically. The concept of causal necessity is substituted by the concept of large probability. This is in sharp contrast to the Newtonian-Laplacean notion of absolute predictability. (It has to be mentioned here that the idea of perfect predictability in the Newtonian-Laplacean framework has also been undermined by the application of "Godelian Sentences", see Popper, *1950).*

The Perfect Object-Subject Distinction

One other important element of modern physics which is connected to the idea of uncertainty and predictability is the impossibility of the sharp separation of the object and subject. This can be seen by using a thought experiment. The observer uses a g-ray microscope to observe the position of the electron. In the act of observation at least one quantum of the g-ray must have passed the microscope and the electron deflects it. Thus, the g-ray quantum has "pushed" the electron and has changed its position and velocity (Heisenberg, 1958:47-50).

One could have also guessed this in the previous analysis of the nature of probability. The concept of the interference of probabilities is vitally connected with the act of observation in the sense that the measurement itself affects the probability. Heisenberg asserts that "The observation itself changes the probability function discontinuously" (Heisenberg, 1958:54). He proceeds to make some general methodological comments about the consequences of this characteristic of modern physics. In particular, he thinks of the separation between object and subject in classical physics, and generally in science, as coming from the Cartesian mode of thought.

"Natural science does not simply describe and explain nature; it is part of the interplay between nature and ourselves; it describes nature as exposed to our method of questioning. This was a possibility of which Descartes could not have thought, but it makes the sharp separation between the world and I impossible." (Heisenberg, 1958:75).

Other physicists have made similar comments on this extremely crucial point. Bohr, one of the founders of quantum mechanics, also believes that observation in physics is treated as interaction between the physical elements. In particular, he held that the objectivity of science is a function of the concept with which experience is described (Folse, 1985:217). M. Born also points out that in modern physics "subjectivity is primary and the possibility of objective knowledge problematic" (Born, 1964:233).

4. Implications for Economic Methodology

The previous discussion of the philosophical implications of the new physics is quite important for two reasons: the first is that many economists still regard physics as a model for science, and this justifies the scope for studying the new scientific philosophy of physics. The second is that modern physics has significant implications for scientific enterprise in general. In particular, the protagonists of quantum mechanics see their ideas as having relevance for scientific methodology in general, not only physics. More specifically, they see quantum mechanics as a general case and that of classical physics as a limiting, special case (Heisenberg, 1962:41). Heisenberg, for instance, assesses the implications for disciplines such as Chemistry and Biology. (Actually modern biologists have incorporated the concept of indeterminacy and unpredictability in modern approaches to evolution Simpson, 1967). The same is done by Bohr and Born and other physicists. Their involvement in scientific method is such that they criticize established scientific philosophies. For instance, Heisenberg (1962:76-78) and Bohr (1958) attack the positivist philosophy of science and especially logical positivism. Furthermore, Heisenberg has explicit reservations about what he calls the Cartesian framework which dominates scientific method.

In addition, modern philosophers of science have been influenced by the revolution in physics and its epistemological implications. Most of the influential contemporary philosophers have often referred to the broad consequences of modern physics for the philosophy of science.

The examples of Popper, Kuhn and Feyerabend are indicative (see for instance Kuhn, 1970).

Thus, if one accepts the significant implications of quantum theory for scientific method in general, it follows that the above methodological arguments are of relevance also to economics. Indeed, many economists still regard physics as the ideal science. In general, the main methodological ideas of many neo-classical economists are part of the Cartesian or hypothetico-deductive method. The new scientific philosophy actually undermines this. Moreover, it also undermines the instrumentalist stance which has become influential in economics during recent decades. Heisenberg (1958), for instance, explicitly saw the uncertainty relations as a characteristic of nature. In the same spirit, Bohr conceived complementarity as derived from what he regarded to be a fact of nature, "that interaction at the atomic field takes place in discontinuous, unpredictable transitions" (Bohr, 1958; Folse, 1985:229).

The revolution in physics has serious implications for the conceptions of uncertainty, prediction and scientific detachment. First, our previous discussion indicates that the conception of uncertainty for the majority of economic theorists is epistemic and in principle reducible. This also holds for many econometricians. The related idea of prediction as the sole criterion and purpose of economic science is also undermined. Moreover, the complete separation of object from subject which is one of the basic methodological points of standard economics should also be seen from a different viewpoint. One can actually combine the methodological implications of modern physics with alternative ideas of economists on uncertainty, prediction and scientific detachment.

Uncertainty

It is possible to make a connection between the irreducible uncertainty of quantum physics with similar approaches in economics. Although there are differences among these approaches, their common characteristic is the similarity with the new conceptual framework that prevails in contemporary physics. Knight's (1933:220) conception of probability as aleatory "due to real indeterminateness in the cosmos" provides some initial signs of similarity with quantum mechanics (Lawson, 1988). His conception of uncertainty is consequently close to the notion of indeterminacy that we discussed. More specifically, according to Knight, there are basically two types of uncertainty: 1) measurable uncertainty which corresponds to *a*

priori and statistical probability and 2) unmeasurable uncertainty which corresponds to "estimates" or unmeasurable probability. Knight, as we have seen, argues that the first type is not real uncertainty but risk (Lawson, 1988). The second type is the real or genuine uncertainty. Clearly the second type of Knight's uncertainty is quite different from the standard calculable uncertainty used by many economists, but is similar to the notion of uncertainty in modern physics.

Although Shackle's conception of uncertainty is different from that of Knight, it is still closer to the new methodological spirit than the orthodox conception. He believes that there are two major categories of experiments: 1) seriable or divisible and 2) non-seriable or non-divisible experiments (Shackle, 1955, 1974). A good example of the former is the rolling of dice a large number of times. The question of a given individual reaching the age of 70, is an example of the latter category. The relative frequency approach to probability is applicable to seriable experiments (Shackle, 1961) . However, this situation is not real uncertainty. Shackle connects real uncertainty with non-seriable experiments and argues that the concept of probability is not appropriate in these cases. A new concept called "uncertainty variable" is used which is the starting point of building a whole new theory of decision making under real uncertainty (Earl, 1983, Stephen, 1986). Although this approach is different from the ones already discussed, it is not very far from the spirit of the new scientific philosophy.

P Davidson's (1983) conception of uncertainty is a more recent example of similarity to the new paradigm. He uses the term *ergodic* to describe situations where phenomena are replicable (thus uncertainty is reducible or closer to risk in Knight's sense) and where mechanical time is used. In an ergodic world, agents can in theory gradually reduce uncertainty (Carvalho, 1988). As was seen, this situation is very similar to the dominant conception of uncertainty. A non-ergodic situation is characterized by indeterminacy, non-repeatability and time is real. Also in a non-ergodic world the probability function is changing over time (Davidson, 1987). Davidson's interpretation of Keynes is such that it enables him to believe that a Keynesian world is basically a non-ergodic one (Davidson, 1983). Clearly, in terms of our previous discussion, an ergodic world is basically a classical physics world, while a non-ergodic world is closer to the new methodological paradigm advocated by modern physics and the new philosophies of science.

Keynes thinks of probability as epistemic and thus his conception of uncertainty is epistemic too (Keynes, 1973, Lawson, 1985). To him

uncertainty is characterized by the absence of knowledge of probability relations (either because there is none or because they cannot be known). Thus, uncertainty corresponds to a situation of numerically immeasurable probability.

"The game of roulette is not subject, in this sense to uncertainty; nor is the prospect of a Victory bond being drawn. Or, again, the expectation of life is only slightly uncertain. The sense in which I am using the term is that in which the prospect of a European war is uncertain, or the price of copper and the rate of interest twenty years hence . . ." (Keynes, 1973, XIV:113-114).

In spite of his belief that uncertainty is not calculable, it should be pointed out that his epistemic conception of it puts him at odds with the modern physics paradigm. Like modern physicists, Keynes emphasized the importance of uncertainty but his approach to the whole concept of uncertainty was different (Lawson, 1985, Stohs, 1980; Garner, 1983, Weismann, 1984, Carvalho, 1988).

Finally, it should be mentioned that there are some econometricians who interpret the stochastic element in non-Bayesian econometrics as indicating real irreducible uncertainty. Actually one can trace the influence of those theorists to quantum mechanics (see Mirowski, 1989b).

Prediction

The predictive ability of a theory is the most important criterion for theories according to many neo-classical economists. However, if one still wants to follow the methodological paradigm of physics, then a pure predictionist position in modern economics is difficult to sustain. This is because of irreducible uncertainty which, in essence, makes prediction much more probabilistic. Moreover, the anti-instrumentalist attitude of physicists like Bohr and Heisenberg is another reason to doubt the predictionist stance.

If prediction as the prime criterion of theories is undermined, then there is ground for other stances like explanation or understanding. There are a number of scientific subfields where prediction is not considered as the prime criterion; rather explanation is thought to be more appropriate. Evolutionary biology, which is a very successful discipline, has explanation as its first criterion. Geology is another example.

Keynes can also be seen as an economist who was against the extreme

emphasis on prediction. He criticized the prevailing idea of the economic model being a vehicle for prediction. Rather, he pointed out that models should be seen as vehicles for analysis and understanding (Keynes, 1973:296; Deane, 1978; Lawson, 1989a). In addition, his preference for an organic rather than a mechanical approach to economic phenomena is indicative (Rothein, 1988; see also Gerrard, 1991 on the different interpretations of Keynes).

Apart from Keynes, some subsequent theorists have de-emphasized prediction and placed more attention on understanding and explanation (e.g Samuels, 1974; Dow, 1990). Furthermore, one of the basic ideas of Lawson's "realist" methodological approach is that the main criterion of theory adequacy is depth of explanatory power rather than predictive accuracy (Lawson, 1989b). It is also possible to make connections with new approaches to causation which are much less based on deterministic prediction. The INUS conditions which imply much looser causality, might be seen as closer to the new framework (Addison, Burton and Torrance, 1984).

Scientific Detachment

The dominant position as far as the issue of complete separation of subject and object in economics is expressed by Friedman (1983) and Lipsey (1984). Both believed in the idea of a complete value-free economic science and effectively in the methodological possibility of excluding value judgments. The completely opposite viewpoint is represented by Myrdal's (1953) thesis which denies any possibility of excluding value judgments. In between these two views are others who are willing to accept some degree of objectivity-subjectivity. Blaug's position, for instance, is that although in practice the opinions (value-judgments) of the researchers play a role in scientific analysis, he believes that it is methodologically possible to exclude these opinions completely (Blaug, 1980:129-156). Hutchison is closer to Myrdal, and supports the view that value judgments affect the formulation of scientific hypotheses and that these values can take the form of "preconceptions, predilections, presuppositions, ideologies and social and political philosophies" (Hutchison, 1964:60-63). (Moreover, this methodological position is not far from the views of alternative schools of economic thought.)

The scientific paradigm of modern physics implies that the act of observation cannot be entirely objective. Thus, the positivist ideal of a completely

objective observation is seriously undermined by the new methodology. If one also considers the far greater complications with regard to the (uncontrollable) nature of observation in social sciences, then the importance of this point is even more significant. Chick's (1990) link of uncertainty and Chaos theory to economic method reinforces this stance. In other words, if one still wants to adopt physics as the scientific ideal for economics, the implication is that the methodological position of Myrdal and Hutchison seems to be more relevant than that of Friedman and Lipsey.

In particular, the impossibility of the complete exclusion of normative elements implies an economic methodology where economists should also take into consideration the philosophical, political and sociological dimensions of economic phenomena. This type of methodological approach is akin to ideas expressed by economists like Shackle (1955), Wilber and Harrison (1978), McCloskey (1983), and Dow (1985), who emphasize the role of norms and value systems and the difficulty in separating them from economic theory. In general, methodological ideas which advocate the impossibility of the complete separation, seem to be far more plausible, that is if economists wish to follow the paradigm of physics.

5. Conclusion

Physics has long served as the ideal model of scientific inquiry in the history of economic thought. This is still true for many contemporary economists. The important issue here is that the revolutionary methodological developments in physics have passed largely unnoticed in economic analysis, and models continued to be fashioned in imitation of classical physics. In the above we concentrated on a few important aspects of contemporary economic methodology: uncertainty, prediction and the sharp separation of subject from object. It was maintained that for many economists uncertainty is conceived of as epistemic and reducible; that many theorists think of prediction as the sole goal of economic science; and that most of them believe that the complete separation of object from subject is methodologically possible.

The paper proceeded to argue that modern physics and especially quantum mechanics have created a new scientific methodology. In particular, classical physics is viewed as a special, limiting case. The new methodological framework, which has also influenced contemporary

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philosophy of science, is quite different. It views uncertainty as aleatory and irreducible. Prediction is not seen as the prime purpose of science, and a sharp separation of object and subject is impossible.

The important implication for economics is that if physics is viewed as the ideal model of scientific inquiry (the methodological legitimacy of which is questionable), then some aspects of the prevailing economic method are problematic. In particular, given our discussion of the nature of uncertainty, the predictionist stance is clearly undermined. Also, the idea of complete detachment is not without serious problems. Instead, the new scientific methodology has common features with the views of Knight and Shackle on uncertainty, of Keynes on prediction and of Hutchison and Myrdal on the issue of value-free economics.

The paper has not argued that economics should follow the new scientific methodology. It has argued that as long as physics is regarded as *the* scientific ideal, two points have to be realized: first its methodology has changed radically; second, this implies that some important issues of the prevailing economic methodology are problematic.

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Endnotes

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