Formalising Economics: Social Change, Ideology and Mathematics in Economic Discourse

Dimitris Milonakis

University of Crete

(d.milonakis@uoc.gr)

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Abstract

Excessive mathematisation and formalisation of economic science has been one of the most important features of the development of economic science in the later part of the twentieth century. What were the causes behind this excessive mathematisation of economic science? Why did it happen when it did? These are the main questions I try to explore in this paper. Recent scholarship places excessive emphasis on the role and prestige of mathematics as a scientific tool. The processes of mathematisation and formalisation of economics are, however, complicated, involving social, economic, intellectual, ideological and institutional factors, and so simple mono-causal explanations are inadequate. In this paper we try to partly redress the balance and bring to the fore some of these factors involved in these processes, including the role of (liberal) ideology in each phase of the mathematisation process.

Keywords: Newtonianism, formalism, mathematics, rigour, ideology, liberalism, marginalism, Cold War.

Excessive mathematisation and formalisation of economic science has been one of the most important features of the development of economic science in the later part of the twentieth century, following what has been dubbed the "formalist revolution" of the 1950s (Ward, 1972, Hutchison, 2000, Blaug, 1999, 2003). What were the causes behind this excessive mathematisation of economic science? Why did it happen when it did (i.e. in the second part of the twentieth century)? These are the main questions I try to explore in this paper.[1]

Scholarship over the last three decades, including Ingrao and Israel (1990), Mirowski (1989, 2002), Weintraub (1985, 2002), has helped in shedding light on some of the intellectual factors involved. These accounts tend to rely heavily on one or two factors alone. Most prominent is "the enormous, often uncritical, awe of mathematics in Western Culture" (Lawson, 2003, p. 248); and for (Ingrao and Israel, 1990, p. 34), "The historiography of philosophical thought has long identified the 'mathematisation' of the social sciences as one of the major themes of contemporary culture generated and molded in the rich melting plot of the Enlightenment". So pronounced is this tendency of "awe" that it has led one leading critic to describe it as a form of ideology (Lawson, 2012, pp. 11, 16). This account, although shedding important light to one of the intellectual factors involved, leaves some important questions unanswered. If the importance of mathematics in Western Culture is the basic causal factor, why, for example, did this formalisation process only take place to such an extent after the Second World War? Lawson (2003, pp. 250-9) attempts to answer the question of why the mathematisation process took off when it did through a natural selection evolutionary process together with a distinctive environmental shift which was favourable to the adoption mathematical methods in economic discourse. The processes of mathematisation and formalisation of economics are, however, complicated, involving social, economic, intellectual, ideological and institutional factors, and so simple mono-causal explanations are inadequate. In this paper we try

[1] I would like to thank Ben Fine for his painstaking comments on an earlier and much longer draft of this paper. This earlier version was presented at the 4th Annual IIPPE Conference in the Hague in September 2013 under the title "Formalism and Mathematics in Economics Discourse: a Potted History with Some Partial Explanation". My thanks go to the participants of the conference who were present in my presentation for stimulating comments. Any remaining errors are mine alone. A much longer version of the current paper under the same title is available upon request from the author.

to partly redress the balance and bring to the fore some of the factors involved in this process.

In section 1 we examine the prehistory of the mathematisation process until the 1870s. In it we delineate the role of Newtonianism and liberalism in the formative years of political economy as a separate branch of knowledge by focusing on Smith's attempt to blend the two, and we try to tackle the important question of why all attempts to mathematise economic science utterly failed during this period. In section 2, the first concerted efforts to mathematise economics which took place during and in the aftermath of the marginalist revolution are scrutinised. These involve the works of Jevons and Walras and their followers through the imitation of the methods of natural sciences and prepared the ground of what was to follow about half a century later. The inbuilt ideological biases of neoclassical theory based on marginalist principles is also exposed. Section 3 examines the changes occurring both within economics through its desocialisation and dehistorisisation and in the natural sciences following the crisis in physics with the appearance of relativity theory and quantum mechanics at the turn of the century and Hilbert's Program in mathematics, which also had an impact on economics.

The 1930s which was probably the most crucial decade in the process of the mathematisation of economics is the subject of section 4. The social, ideological, institutional and intellectual developments that took place during this heated decade, including the Great Depression and Roosevelt's New Deal, the ideological dominance of socialism over liberalism, the formation of Econometric Society and the Cowles Commission in the 1930s in the U.S.A., and the rediscovery of Walrasian general equilibrium theory, come under close scrutiny. The consolidation of this process in the 1940s through the appearance of two milestone monographs is examined in section 5. In the same section the role of the War through its impact in scientific developments and through that in economics is considered. Section 6 tells the story of the 1950s, the decade during which the formalist revolution took off the ground. Arrow and Debreu were the two most important figures in this process. Section 7 brings to the fore the causal role of ideology in directly shaping developments in economics in the context of the Cold War McCarthyism.

1. The Prehistory

The Enlightenment represented the triumph of reason over metaphysics. The Scientific Revolution, the emergence of (classical) liberalism and the birth of economic discourse were all children of the same cultural environment, the rise of trade and capitalism and the technological advances in Western Europe during the sixteenth and seventeenth centuries, with the former also feeding into the latter in significant ways. Reason (rationalism), individualism, liberalism and universalism were the main Enlightenment values.

The publication of Newton's *Principia Mathematica* in 1687 signified the climax of the Scientific Revolution which took place during the fifteenth and seventeenth centuries. Voltaire was responsible for bringing Newtonianism to France which by the 1750s had become "the scene of Newtonianism's most fruitful developments and greatest triumphs" (Ingrao and Israel, 1990, p. 35, Schabas and de Marchi, 2003). The French Enlightenment has bequeathed upon social sciences, and economic discourse in particular, four major features. First is the idea of the existence of laws governing the social cosmos. Second is rationalism. Third is the concept of harmony and equilibrium. And fourth is the bringing of the individual, emancipated from societal and other fetters of ancient and medieval times, to the fore for the first time in history.

Individualism and individual liberty in opposition to State power became the cornerstones of classical liberalism, one of the main philosophical traditions of the Enlightenment which was "a reaction against mercantilism feudal and aristocratic societies of the *ancient régime*", with John Locke and Adam Smith as the two main representatives (Cockett, 1994, p. 5). Between 1760s and 1820s was the period when the battle of liberalism against mercantilism was fought and won, with liberalism becoming the ruling dogma for the best part of the nineteenth century (p. 6).

Ever since the publication of Newton's *magnus opus*, social scientists have been asking the question: if nature is governed by laws could the same be the same for society? Some have translated this into the following related but different question, "is it possible to apply or adapt the methods of inquiry that have proved so effective in the physicomathematical 'exact sciences' to the study of man's moral, social and economic behaviour?" (Ingrao and Israel, 1990, p. 33). The difference between the

two questions, is not semantic and involves very different answers, methods and modes of expression, with narrative discourse and mathematical reasoning being two important candidates.

In their ground-breaking work on the process of mathematisation of economic science, Ingrao and Israel (1990) focus exclusively on the work of mathematical economists, especially those who somehow dealt with general equilibrium models (p. 34). This indeed seems to be the starting point of most, but not all, attempts to apply the mathematical method to economic discourse. However, by opening up the picture to include the development of economic science as a whole, and not of mathematical economics alone, a very different perspective emerges on developments during the prehistory period of the mathematisation of economic science. It can be broken into two sub-periods, from the mid- to late-eighteenth century, when mathematical reasoning did gain some currency among writers on economic matters, and the period between the end of the eighteenth century and 1870 when mathematical economists failed to make any impact whatsoever. Overall the picture that emerges from this period is one consisting mostly of a systematic *failure* of mathematically-oriented economists to make any substantial inroads into the dominant economic thinking of the day, i.e. classical political economy. If this is the case, the crucial question to tackle in an attempt to explain the later mathematisation of economics, is why did these earlier attempts fail? This is of crucial importance if one is to avoid teleological arguments based on mathematical awe or otherwise and bring to the fore important factors of resistance to the mathematisation tendency in economics.

To answer this question we need to go back to the beginning of this period. The publication of Newton's *Principia Mathematica* in 1687 had an impact both on the Scottish and the French Enlightenment. For Scottish moral philosophers, “moral philosophy was to be transformed into an uncompromising empirical science. That, in any case, was David Hume’s (1711-1776) message when he presented his *Treatise on Human Nature* (1739-4) as an ‘attempt to introduce the experimental method of reasoning into moral subjects’” (Heilbron, 2003, p. 44). Similarly, following the importation of Newtonianism in France, one of the basic questions posed by authors of the French Enlightenment, Montesquieu and Quesnay in particular, was whether social reality is also governed by laws. The first attempts at introducing mathematical reasoning into economics were conducted in France mostly by members of the

Physiocratic movement, in particular Quesnay, Turgot and Condorcet (Ingrao and Israel, 1990, ch. 2, Heilbron, 2003, pp. 43-7).

During the classical era stretching between 1776, the year of the publication of Adam Smith's *Wealth of Nations*, and the 1870s, there were several scattered attempts by individual writers to introduce mathematical reasoning into economic discourse.[2] One common characteristic of all these attempts was that they failed to have any impact whatsoever and soon fell into oblivion. So total was this oblivion, that when Jevons and Walras ventured into constructing mathematical models of price determination in the 1870s, they had to (re)invent most of these concepts anew (Howey, 1973, pp. 25-6). As Jevons (1957, p. xliii) writes in 1879, "the unfortunate and discouraging aspect of the matter is the complete oblivion into which this part of the literature of Economics has fallen, oblivion so complete that each mathematico-economic writer has been obliged to begin almost *de novo*" (see also Fisher, 1925 [1892], p. 109, and Robertson (1949, p. 535) both in Theocharis, 1993, p. viii, Robbins, 1983, p. xi). The interesting question then is to explain why did this happen and what changed in the 1870s when mathematical economics began to gain some currency among economists?

Following the impact of the publication of Adam Smith's *Wealth of Nations* in 1776, the search for *mathematical* laws in the economic and social realms considerably subsided. The same, however, did not apply to the quest for *laws* governing the social cosmos. To the contrary, the explicitly stated aim of most classical economists was indeed the search for such laws. Smith wrote at the beginning of the industrial revolution which represented a threshold between the early merchant phase of capitalism of the sixteenth and seventeenth centuries, and the industrial capitalism of the nineteenth century. As the title of his magnus opus suggests, Smith's main aim was to discover "the nature and the causes of the wealth of nations".[3] As a true child of the Enlightenment, Smith's work was a prime instance

[2] The first endeavours to mathematise economics during the classical era were conducted by writers such as Isnard and Canard, von Thünen, Cournot, Karl Heinrich Rau, Dupuit and Gossen (Theocharis, 1983, chs. 5, 7.4, 9; 1993, chs. 4, 6, 7, 9).

[3] For Ricardo, Mill and Marx, political economy has similar aims all offer similar centering around "the laws which regulate the production, distribution and consumption of wealth" (Mill quoted in Milonakis and Fine, 2009, p. 13).

of the attempt to blend the search for societal laws with the values of liberalism. The first is the result of the application of the scientific method to the analysis of the social universe, while the latter is built on the principles of natural liberty and individual freedom. Individualism, economic liberalism and universalism form the main building blocks of his theory. This is reflected in his search for causal factors behind capitalist development, the division of labour and the increase in productivity, in the individual's natural (hence universal) propensity "to track barter and exchange", and his proclivity to pursue his own self-interest, a quest that results in increased social welfare. Having said this, Smith's analysis is full of instances where he deviates from this basic schema, including the wide and multifaceted use of historical analysis and the deployment of more collectivist (class) analysis alongside his individualist arguments. Most Enlightenment and classical writers "rejected the mechanical model of human behaviour" by refusing to draw a sharp distinction between economic and non-economic motives, considering both to be constitutive of human nature (Hillinger, 2015, p. 59, da Fonseca, 1991, ch. 3). Smith was a prime example of this Enlightenment feature through the identification of sympathy (in his *Theory of Moral Sentiments*) as a pro-social motive of human conduct alongside self-interest

Although classical liberalism continued its journey not least through the writings of John Stuart Mill, becoming the ruling dogma of the nineteenth century, it did not go uncontested (Mill, 1962a, 1962b). The socialist movement which sprung out in the 1820s in the form of the writings of the French socialists (Saint Simon, Fourier and the anarchist Proudhon) and culminated in the work of Carl Marx, was the child of the adverse consequences of the industrial revolution and the turbulences of nineteenth century industrial capitalism. At the same time the mode of analysis of the main classical thinkers Ricardo and Marx (Mill's was more individualist and more eclectic) was moving away from individualism towards more holistic and collectivist (class) types of analysis influenced, in Marx's case, by Hegelian dialectics, and in the case of the German historical school to more historico-inductive forms of analysis.

In such an intellectual environment, although Newtonianism's influence is still present in the form of the quest for social laws, the same does not apply to Newton's, and the physical sciences' more generally, tools. Classical political economists adopted mostly a discursive (conceptual) mode of expression characterised by "long chains of verbal reasoning", and "argued in terms of principles and laws, not models."

(Morgan, 2012, pp. 45-6 and ch.2). Why was this the case, and why did these laws not take the form of mathematical laws?

First, in the late eighteenth century the intellectual atmosphere was changing making it less conducive to the use of mathematical tools outside the natural sciences. This was reflected in the doubts expressed first by the *ideologues* concerning the use of the physico-mathematical method in the social sciences by the Physiocrats, then by pioneers of the emerging new social science, especially Auguste Comte, and by members of the classical school of political economy such as Say who were thoroughly against the use of mathematics in social science (Ingrao and Israel, 1990, pp. 54-60). Second, this was the era of what has been called Counter-Enlightenment which is associated mostly with the rise of German Romanticism, which substitutes emotions for Enlightenment's rationalism, and is associated with relativism, anti-rationalism and organicism.

Third, unlike their mathematical counterparts who were mostly trained in the natural sciences, most classical economists, with the exception of Ricardo who was a broker, were either philosophers themselves or had some (initial) training in philosophy. Fourth, writing either during the course of the industrial revolution or in its immediate aftermath, they were mainly concerned with issues of long-term development and growth. Fifth, and derivative upon the second, they were interested in issues of economic policy and reform (revolution even). Sixth, their focus of attention was the (capitalist) economy which they treated as a dynamic system and which they conceived in its wider social and historical context. Hence social relations and historical processes featured prominently in their analysis.[4] Directly related to this is the relative priority they gave in qualitative over quantitative analysis. Although quantitative questions are never absent from classical writers, these are at most narrower applications of their qualitative analysis. In effect what most classical political economists sought was the construction of a unified social science in their attempt to explain the workings of the (capitalist) economy. Social relations and historical processes, however, are notoriously difficult to analyse mathematically, as are issues of long-term dynamics and growth in a historical and social setting. The

[4] This is especially true of Smith's and Marx's analysis while Ricardo, whose abstract analysis although social in nature lacked a strong historical dimension, is a sort of an exception.

same applies to issues of economic policy which require normative analysis (Milonakis and Fine, 2009, ch. 2). Granted all these features, it was natural that classical economists eschewed mathematical reasoning since it was simply unsuitable for the grander purposes at hand. For the same reasons those who strove to mathematise political economy during this period failed utterly in their task.

2. The First Rupture

With this situation during the classical epoch, what changed in the latter part of the nineteenth century to bring about the first self-confident, and partly successful, attempts to introduce mathematical reasoning in economic science, first taking shape in the writings of Jevons (1835-1882) and Walras (1834-1910)? Classical political economy had been in deep crisis from roughly 1850 and under continuous attack from many different quarters and theoretical view points such as the German Historical School, Karl Marx and then the marginalists. The marginalists in particular had a clear aim of transforming economic science away from holistic, collectivist and inductive modes of analysis, towards more abstract and individualistic types of analysis. Despite their open hostility both to classical political economy and Marx and to the German historical school, neither Jevons nor Walras engaged directly with any of their opponents. It was left to Menger to engage with the leader of the German historical school Gustav Schmoller over the relative merits of the abstract and the historical method, and to Menger's disciple Böhm Bawerk to try to demolish Marx's theory of value from an individualistic and subjectivist perspective (Menger, 1985 [1883], Sweezy, ed, 1949).

One common characteristic of most mathematical economists examined so far is that they were typically trained in some natural science or other (Ingrao and Israel, 1990, chs 2, 3, Theocharis, 1983, chs 5, 9). This same attribute is shared by most of the crusaders of new economic thinking who wrote in the marginalist tradition. What is new with them is that first, although they wrote separately, their writings coincided in time, and, second, that they managed to attract followers including the likes of Edgeworth and Pareto in Europe, and Fisher in America.

Second, another novel element is that this is the first time that the transformation of economics into a mathematical *science* on a par with natural sciences becomes a programmatic proclamation. This involves the strict separation of positive analysis from normative analysis, with the latter being preserved for other branches of knowledge such as applied sciences, moral sciences and arts (see Walras (1954 [1874], pp. 52, 60, 76-80, see also Milonakis and Fine, pp. 94-5). Walras excludes questions of wealth, well-being, property, justice and distribution from the work of an economic *scientist* or, in other words, the sum total of the questions focused upon by classical political economists. The change could not be more dramatic in this respect.

This is also the first time that three main elements of the French Enlightenment, individualism, the concepts of harmony and equilibrium, and the idea that the economic realm is governed laws, are applied with such force and vigour. But now, this application is associated with either a transformation of the meaning of the concepts involved, or with a more specific understanding of it. First, the more rounded conception of the individual and of human nature, nurtured by the representatives of the Enlightenment and classical political economy, including Hume, Quesnay, Smith and J. S. Mill, now gives its place to the narrow conception of economic man, or *homo economicus*. With the advent of marginalism, following Bentham's philosophy of utilitarianism, all non-economic elements in the form of ethical, pro-social motives such as Smith's concept of sympathy, disappear from the map of human nature, which is now understood as being moulded by purely selfish economic motives. According to Fonseca (1991, ch. 3 quoted in Hillinger, 2016, pp. 60-61) "The central feature of the metamorphsis of economic agents into 'pleasure-machines' is that they cease being moral persons …" (see also Milonakis and Fine, chs. 2, 5, Hillinger, 2015, ch. 2.3). This move is essential for the construction of a more abstract type of reasoning lending itself more readily to mathematical analysis by formulating individual action in quantitative-mathematical terms. Further, the focus on the (amoral, asocial) individual drives the analysis away from classes and their dangerous, antagonistic connotations.

The methodological individualism deployed by the marginalists and neoclassical economics more generally is a first clear sign of its ideological leanings with liberalism. This is a reflection of the ideological climate of the time. The

nineteenth century was the age of liberalism. Economic liberalism as the economic expression of political liberalism reached its peak during the 1870s and 1880s in Britain by becoming the "governing principle of both the Liberal Party, under Gladstone, and the Conservative Party, particularly under Disraeli, up to 1880" (Cockett, 1994, p. 13).

The implicit ideological bias of neoclassical economics does not stop here. On top of the concept of economic man or homo economicus, the other scientific foundations on which neoclassical economics was erected was the concept of equilibrium borrowed, quite appropriately, from static mechanics, the introduction of the change at the margin (marginalist principle) as a basic economic principle of human decision making, and the concept of economic (Pareto) efficiency. Each of these seemingly "neutral" foundation stones of modern economics had inbuilt ideological biases.

To begin with, the concept of equilibrium and perfect competition is far from neutral. Equilibrium implies a harmonious, smoothly running system, free from internally generated interruptions, which if left on its own will always return to a state of equilibrium. This has the essential function, whether intended or not, of driving the analysis away from issues such as economic crises, downturns and depressions, a recurrent phenomenon of nineteenth century economic life at least since the end of the Napoleonic wars. Perfect competition, on the other hand, is a model of the economy close to the liberal ideal laisser-faire capitalism, of free, perfectly functioning markets. Similarly, focusing on decisions taken on the basis of marginal changes in the quantities involved, moves the attention to small, smooth, piecemeal economic and social change and away from long term, revolutionary social change which is the Marxist moto. Last in our list, is the concept of Pareto efficiency which also has important ideological connotations as it is distributionally blind, implying that distribution does not matter. Such an "objective" criterion could help legitimise even the most extreme form of inequality.

Granted these foundations, economic laws can now be expressed in mathematical form which was an explicitly stated aim of the marginalists. Thus for Walras (1954 [1874], pp. 71-2) "[the] pure theory of economics is a science that resembles the physico-mathematical sciences in every respect" (see also Jevons

(1957, pp. vii, xxi). As Mirowski (1984, 1989, ch. 5, 1991, p. 147) has shown, the first major rupture in the mathematisation of economics is associated with *physics envy* expressed chiefly, but not exclusively, through the adoption of the mechanical metaphor of equilibrium concurrently by different authors.

The self-confidence and self-assertiveness of Jevons' and Walras' statements above are unmistakable - as is their search for scientific credentials in the form of the mathematical method which was to become the *leitmotif* of economic science in the latter part of the twentieth century. But why is this the case? What are the specific features of the "new" economic science that rendered it susceptible to mathematical reasoning? First is that economics is now depicted as a quantitative science. According to Jevons (1957, pp. vii, xxi), since economics "deals with quantities, it must be a mathematical science". This is possible because capitalism is the first economic system where the economy assumes some sort of autonomy from the other spheres of social reality, and where commodity production and market relations become ubiquitous, transforming social relations into quantitative relations between commodities. Second, is the adoption of deduction as the chief method of economic investigation by all the marginalists. Although the application of the deductive method does make the use of mathematics mandatory in any way,[5] it does facilitate the use of mathematics as the two share the same logical structure (Debreu, 1986, p. 1261).

Third, the focus of attention now shifts away from issues of development and distribution involving social relations and historical processes taking place in historical time, to the atemporal, static issue of price determination analysed in terms of equilibrium. Fourth is the shift away from issues of long-term economic and social change and dynamics to (very) short-run individual maximisation and decision making at the margin. But the very notion of a marginal magnitude is a mathematical concept involving differential calculus. Hence mathematical reasoning becomes indispensible to economic theorising.

[5] David Ricardo and the representatives of the Austrian School (especially Menger and von Mises) are two prime examples of authors using the deductive method while eschewing the use of mathematics.

There is no question then that the marginalist revolution laid the foundations which made the mathematisation of economic science possible: rationality and individual maximisation, equilibrium and marginal analysis, were all tools used, even if not invented, by the early marginalists. It was not, however, until seventy of eighty years later that the full potential of the mathematisation process was realised. Why was this the case and what are the causes of this delay in the forward march of marginalism and of establishing the mathematical mode of expression as the chief tool of economic reasoning?

To begin with, developments in the real economy were moving in the opposite direction to a perfectly functioning market as depicted in the model of perfect competition. This is the era of the rise of large corporations, trade unions and labour law as well as technological dynamism, all of which were outside the purview of neoclassical economics except for Marshall's analysis beyond the organon. At the same time, starting from the 1880s, there is a discrete change in the ideological climate, what has been described as a change from the "age of individualism" to the "age of collectivism". This era was stamped by the foundation of the Fabian Society in Britain in 1884, "the first organisation to formulate and aggressively and successfully promote a coherent intellectual justification for the extension of the power of the State in pursuit of certain specific aims", which started to be implemented in the early twentieth century through the introduction of a range of welfare measures including old age pensions and social insurance (Cockett, 1994, pp. 14, 15). "This steady march of collectivism was … given a tremendous fillip by the first World War, when the demands of war saw the final buckling of the Victorian liberal state, giving way to an unprecedented degree of central control and central economic planning, measures which were … supported and carried through by politicians of all parties …" (p. 15-16). At the same time, even more radical changes in the same direction were taking place in Russia following the Bolshevik revolution of 1917. It would not be far off the mark to say that the interwar years in particular were stumped by the ideological triumph of various forms of socialism and collectivism. As one leading liberal commentator writing in the aftermath of the Russian revolution puts it, "Socialism is the watchword and the catchword of our day. The socialist idea dominates the modern spirit. The masses approve of it. It expresses the thoughts and feelings of all; it has set its seal upon time. When history comes to

tell our story it will write above the chapter “The Epoch of Socialism”” (von Mises, 1981 [1920], p. 15). Free market ideology then was on the retreat, leaving little space for the further development and elaboration of neoclassical economics, the advocates of which were also skeptical about the ability of free markets to deliver the goods (Burgin, 2012, p. 15). Faith in free markets was delivered a further blow by the Wall Street crash and the ensuing Great Depression. All in all, neither the ideological climate nor the socio-economic conditions were conducive to the further advancement of neoclassical economics. The latter was simply not in tune with the spirit of the times.

As far as economic science is concerned, the first part of the twentieth century was a period of pluralism in economics. Thus in the USA the dominant school of thought was old or American institutionalism with its main representatives being Thorstein Veblen, John Commons and Wesley Mitchell, while in Germany the German Historical School still reigned supreme. What brings those schools together, in addition to their common emphasis on institutions, organicism and development, is their common opposition to the marginalist principles and to the use of mathematics in economic discourse (Yonay, 1998, Morgan and Rutherford, 1998, Milonakis and Fine, 2009, chs. 5, 9, 10). Neither of these schools lends itself for mathematical elaboration. Hence the fate of the mathematisation of economic science was bound together with neoclassical economics which did lend itself for this purpose. Given, however, the association of neoclassical economics with free markets this was not the most fertile period for this school to flourish.

Another obstacle in the way of further mathematisation of economic science, was the initial reaction both on the part of fellow political economists but also among some leading mathematicians and physicists of the time which was anything but enthusiastic. Walras’ *Elements of Pure Economics* in particular, which for some was the pinnacle of the marginalist revolution, was initially almost totally ignored by his fellow economists, while the work of early marginalists more generally received a rather cool or even hostile reception by first rate mathematicians and physicists such as Poincaré, Volterra, Bertrand, Levasseur and others for their “abstract schematism and poverty of direct interpretative results” (Ingrao and Israel, 1990, p. 111, also pp. 110-112, 154-173; Mirowski, 1991, pp. 148-9; 1989, pp. 241-250, Lawson, 2003, pp. 269-71).

But opposition to the mathematising tendency of marginalist economics also came from within neoclassical economics itself. The third major factor against the forward march of mathematisation was the huge influence of Alfred Marshall's magnus opus *Principles of Economics* (1890) which laid the foundations of neoclassical economics for the next half century and became the chief textbook until its replacement by Samuelson's *Economics* in 1948. For more than half a century Walras' mathematical analysis was buried under the rule of Marshallian economics. Although Marshall was a mathematician, his analysis was mostly verbal and diagrammatic and he eschewed the use of mathematics which he relegated to appendices. Indeed, he was explicitly opposed to the use of mathematics as the chief tool in economic discourse.[6]

Granted his own analysis which eschewed the use of mathematics other than as an auxiliary tool, his strong views on the matter and his wide influence in the course of neoclassical economics, it was natural that neoclassical economics under his influence would be more or less mathematically confined. This is evident in some prominent representatives of neoclassicism during this period such as John Bates Clark, Eugen von Böhm Bawerk, Jacob Viner and Frank Knight who were all non-mathematical (Mirowski, 1991 p. 148).

3. Preparing the Ground

3.1 Social change and ideology

Perhaps the most crucial period for the shaping of modern economic science in the specific direction it took, was the developments during the middle of the twentieth century. This is true of both the intellectual as well as the social, economic and ideological developments of this period. The latter, in particular, were of the outmost importance in this trajectory. If the nineteenth century was the era of the birth of socialism as a philosophical trend, the "short twentieth century" was stumped by the rise of the socialist and communist countries in Europe. Ideologically, socialism was emerging triumphant following after the First World War and free market liberalism was on the retreat. A sense of defeat was evident in the writings of most leading

[6] See Marshll's letter to Arthur Bowley in 1906, in Whitaker, 1996, vol. 3, p. 130.

liberal writers throughout the 20s, 30s and 40s including the likes of Schumpeter, Popper and Hayek, the former duo even predicting the inevitable triumph of socialism (Amadae, 2003, prologue). Keynes even predicted the end of laisser faire in 1924 while, according to Hayek, writing in 1933, “there are few people today who are not socialists” (Burgin, 2012, pp. 13-4).

This comes as no surprise if one takes into account the socio-economic developments of the time. At a time when following the Wall Street crash of 1929, the West was plunged into the vagaries of the Great Depression, the Soviet Union was experiencing exceptional rates of growth. Other socio-economic developments that had a direct impact on developments in economic theory were Roosevelt’s New Deal as a reaction to the Great Depression; the outbreak of the Second World War; and the advent of the Cold War between the USA and the Soviet Union, following World War II. According to one commentator “events and contingencies in the mid-twentieth century would do more to shape the evolution of American economics than any set of ideas alone” (Bernstein, 2001, p. 64). During the Cold War years, the importance of the ideological factor was also powerfully brought to the fore as an important causal factor. In this and the next section we trace these developments and try to identify the ways in which they shaped the evolution of economic discourse.

During this time, despite its decisive victory over the Historical Schools, neoclassical economics in its dominant Marshallian form of the 1920s was not in good shape. In the U.S.A. and in Germany, it had not managed to challenge the dominance of the institutionalists and the historicists, respectively; in France it had not made any substantial headway, as there was general distrust for the concept of utility; and in the U.K. (especially in Cambridge) it was under increasing attack from those such as Joan Robinson and Pierro Sraffa (Mirowski, 1991, pp. 151-2, Morgan and Rutherford, 1998, Yonay, 1998).

But the most devastating blow suffered by neoclassical economics came from the developments in the real economy and especially from the 1929 crash and the Great Depression of the 1930s. For the whole period until the 1929 Wall Street crash, the view that was dominant within neoclassical economics was that markets are efficient, and if left alone they would tend to get back to full employment equilibrium. The result of these beliefs was that, after the 1929 crash, the market was left on its

own to cope with the consequences of the crisis. The ensuing deepest crisis and depression of the twentieth century shook the credibility of neoclassical theory and the belief in the self-regulating abilities of the market almost beyond repair. Or so it seemed at the time.

The Great Depression brought about the rise of fascism in Europe and Nazism in Germany which prepared the ground for the Second World War. At the same time, in the midst of a deep recession and soaring unemployment throughout the developed world, it was natural that the energies of economists should be devoted to the pressing needs of the day and to economic policy rather than high theory, as is reflected in Roosevelt's New Deal, which, on the one hand, had the effect of revitalizing institutionalism, and on the other hand, of increasing the demand for specialists, a process which was further boosted by the advent of the Great War (Bernstein, 2001, pp. 74-5).

3.2 Intellectual Developments

According to Weintraub (1983, p. 18), at the end of the 1920s beginning of the 1930s "the times were still hostile to mathematical economics". Be that as it may, the 1930s also witnessed some theoretical developments which shook the edifice of economic science in more than one and often contradictory ways.

Chief expression of these developments was Keynes' *General Theory of Employment, Interest and Money* published in 1936. Being an authentic child of the Great Depression, the main purpose of this book was directed to finding ways for reversing the downward trend in the economy and curing unemployment. Although Keynes, much like Marshall, was trained as a mathematician and the *General Theory* was a theoretical treatise, it was written in the spirit of the times. Keynes (1973 [1936], p. 298) warned against the excessive use of mathematics in economic discourse while he was also against the use of econometrics (Yonay, 1998, p. 191).

At the same time another process was going on elsewhere in Europe that was going the shape economic science for the decades to come more decisively than Keynes' writings. Some mathematicians in Vienna were rediscovering Walras' general equilibrium theory in the midst of the deepest recession of the twentieth century, reinvigorating in this way the mathematisation of the dismal science project. With the

excision of the social and the historical element from mainstream (neoclassical) economic discourse, the road was open for the fuller mathematisation of economic science, notwithstanding Marshall's objections and the resistance of the old institutionalist, the historical schools, and, later on, of Keynes himself.

Generally, the mathematisation of economics was meant to make economics more "scientific" and more "rigorous". Before we turn to the developments on this front during this crucial decade, it is instructive to put them into the context of the developments in the physical sciences and the changing meaning of "scientific" and "rigorous". Throughout the nineteenth century during which Newtonian physics and rational mechanics dominated the scene, mathematics and physical sciences were fellow travelers. In the late nineteenth century through the work of the early marginalists, a new economics body began to emerge imitating their image (Mirowski, 1989). At the turn of the century the physical sciences, and Newtonian physics in particular, entered a period of deep crisis associated with the emergence of Einstein's relativity theory and the appearance of quantum physics. At the same time, the meaning of formalisation and rigour in the physical sciences was also changing. During the later nineteenth century, the physics envy era of economics when physics was still ruled by static mechanics, the meaning of formalisation and rigour was associated with forging a link between theory and experimental data. As long as the meaning of science was attached to the real world, American institutionalism and historicism with their strong empirical leanings had a good chance of staying at the centre of the stage as, indeed, occurred during the first third of the twentieth century. Following the crisis in the physical sciences, however, and the establishment of the "new physics" of relativity theory and quantum mechanics, Hilbert's Program in mathematics, also called the "Formalist Program', made its appearance in 1918. Mathematics is now "conceived as a practice concerned with formulating systems comprising sets of axioms and their deductive consequences, with these systems in effect taking on a life of their own" (Lawson, 2003, p. 171, Ingrao and Israel 1990, p. 33, Mirowski, 1989, 2002 and Weintraub, 1998, 2002.

Following this, the notion of formalisation and rigour changes and is now associated with axiomatisation, deductivism and logical consistency or "establishing the integrity of formal reasoning chains" (Weintraub, 1998, p. 1843). With Hilbert's Program, mathematics in its new axiomatic form starts to break away from natural

sciences and assumes the leading role (p. 1844). This transformation of mathematics and its assumption of the leading role in science is reflected in the newly-founded self-assertiveness of mathematicians who started applying their abstract tools to subjects which they hitherto considered as lying outside their field of application. In this way a form of *mathematics imperialism* was unleashed: anything that claims to be scientific can be translated into mathematics, including biology and economics. This is the era where the *mathematics envy* associated with increasing axiomatisation, formalisation and abstractness, substitutes for the physics envy of the nineteenth century, eventually giving rise to the "formalist revolution" of the 1950s, to which we now turn our attention (Weintraub, 1998).

4. The Roaring 1930s

Although the "formalist revolution" took off in the 1950s, the intellectual developments which took place during the 1930s opened the way for this revolution to take effect. So what were these developments and why were they so decisive for the mathematisation and formalisation of economics?

First, was the (re) definition of economics in terms of scarcity and choice. What all neoclassical writers from Walras and Marshall to Samueslon and Debreu (see below), despite their big differences, hold in common, is their focus on the actions of individuals as their basic unit of analysis. Until Robbins, however, the definition of economics did not reflect this. Economic was generally defined in terms of its subject matter as the science of wealth or "the study of the ordinary business of life" (Marshall). "Given such definitions it was not clear that economics was a field that could be studied with high level of mathematical rigour" (Backhouse, 2010, p. 100). This was put right by Robbins in a non-mathematical text! In his definition, economics becomes the science "which studies human behaviour as a relationship between ends and scarce means which have alternative uses" (Robbins, 1932, p. 15). So the focus of attention as far as the definition of economics is concerned shifts away from the preoccupation with the study of the economy or the market, however defined, or the causes of wealth and material welfare, to individual rationality, scarcity and choice. So economics becomes the science of (rational) choice. Although this definition was not widely adopted at the time, it gradually did so and especially

following its inclusion in Samuelson's *Economics* in 1948. Rational choice economics reached its pinnacle in Arrow's *Social Choice and Individual Values* (1951).

This switch of emphasis had two important implications. First, it greatly facilitated the process of the mathematisation of economics since, given the appropriate assumptions regarding human behaviour, rationality and choice (especially in the absence of uncertainty) are amenable to mathematical modeling. "His definition suggested that rigorous mathematical methods could be at the heart of economics" (Backhouse, 2010, p. 101).

Second, there was a distinctive change of climate as far as the role of mathematics in economics is concerned. "[T]he 1920s and 1930s witnessed many changes in the antitheoretical and largely antimathematical climate prevailing among professional economists. A decisive push in this direction was later to be supplied by immigration" (Ingrao and Israel, 1990, p. 249). This is reflected in the differences in the constitutions of the two major economics associations, the American Economic Association (AEA) which was founded in 1885 just a few years after the marginalists wrote their treatises, and the Econometric Association founded in 1930, [where there is a distinct change of emphasis of the aims of economic science from the "historical and statistical study of actual conditions of historical life" (quoted in Ingrao and Israel, 1990, p. 146), to "the theoretical-quantitative and the empirical-quantitative approach … [and the] … rigorous thinking similar to that which has come to dominate in the natural sciences" (quoted in Backhouse, 2010, p. 99).[7]]

The distinctive change of climate in favour of mathematical reasoning in economics was reflected in the foundation of two institutions (the Econometric Society in 1930 and the Cowles Commission in 1932) and one journal (Econometrica, founded in 1933 and published by the Econometric Society), all devoted to the promotion of mathematics and statistics in economic discourse. What hitherto had been the aims of more or less isolated individual writers, now became the programmatic goal of two newly-founded institutions which were destined to play a decisive role in the transformation of economics. This is the first time that Jevons' and

[7] Ragnar Frisch and Irving Fisher were among the founding members of the Econometric Society (Weintraub, 1983, pp. 80-81).

Walras' programmatic statements become reflected in some official document, hence providing the first step towards the institutionalisation of the use of mathematics in economic discourse.

At the same time the meaning of "rigour" and "scientific economics" was also changing, in accordance with the developments in mathematics and the physical sciences described above. "Scientific rigour meant logical rigour", in opposition to the meaning attached to the terms before, both in the physical sciences in the nineteenth century, and in economics in the U.S.A. and elsewhere until the 1930s when "scientific rigour meant ensuring that scientific theories were firmly rooted in the real world" (Backhouse, 2010, p. 99).

This change of climate coincides with the influx of a number of mathematicians, scientists and engineers into economics.[8] Importantly, it also coincides with the (re)discovery Walras' general equilibrium theory which, as seen already, had been buried for about half a century under Marshall's flourishing partial equilibrium analysis which was synonymous with the neoclassical economics of the time. What is also new is that this (re)discovery was made not only by economists such as Sir John Hicks but also, and importantly, by some top rate mathematicians who started showing some interest in mathematical economics for the first time, another reflection of the changing climate. The venue for this encounter was Karl Menger's[9] mathematics colloquium in Vienna where some of the top mathematicians of the epoch took part (among them Gödel, von Neumann and Wald). It was during this time that "the foundations were laid for the theory's *axiomatisation*" a process that reached its climax in Debreu's (1959) *Theory of Value* (Ingrao and Israel, 1990, pp. 176 and 175-9, 188-197, Punzo, 1991, Weintraub, 1983, 2002, chs 3,4).

It was not only mathematicians that rediscovered Walras' general equilibrium system in the 1930s. Economists themselves also started showing interest again including Hotelling, Lange and Hicks. The chief moment of this rediscovery by economists, however, was Hicks' *Value and Capital*, published in 1939, which

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[8] Among them Frisch, Hotelling, Tinbergen, Koopmans, Allais, Arrow and Debreu (Mirowski 1991, p. 152).

[9]Karl Menger was a mathematician and the son of the marginalist Carl Menger.

represented a sort of bridge between Walras' *Elements* and Samuelson's *Foundations of Economic Analysis* (1947). Both Samuelson's *Foundations* and, especially, Arrow's work in the 1950s, were attempts to fulfill Hicks' or similar tasks, but on more mathematically rigorous foundations (Weintraub, 1983, pp. 19-21, Ingrao and Israel, 1990, pp. 177-8, 235-244, 260—9, 272-7).

5. Consolidation: From Vienna to the Cowles Commission

In the 1940s, the scene of the further developments in mathematical economics moves across the Atlantic to the U.S.A. which was to become the new centre of modern (mathematical) economics, a hegemonic position it still enjoys until today. The role of the Cowles Commission in this process cannot be overestimated (Weintraub, 1983, p. 18). This coincides with the mass emigration of scientists from Europe because of the rise of Nazism and the war: von Neumann, Wald, Menger and Lange were among them. The array of people who served in the Commission is impressive and represents the *dramatis personae* of mathematical economics of the next two decades.[10]

The 1940s witnessed the next major step in the formalisation and mathematisation of economics. This took the form of two monographs that were meant to play a decisive role in the process: von Neumann's and Morgenstern's *Theory of Games and Economic Behaviour* (1944) and Paul Samuelson's *Foundations of Economic Analysis* (1947). Although these were two different types of books which provided the basis for different research programs in economics and at different times,[11] they both contributed to a great extent in their different ways to the further formalisation and mathematisation of economic science. Von Neumann and Morgenstern's volume represents the first major work in which the new type of axiomatised mathematics was entering economic discourse. It represents the first book-length incident of the newly-founded form of *mathematics imperialism* in economics which had first taken shape in Menger's seminar over the previous decade.

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[10] The list includes the likes of Lange, Wald, Menger, Marschak, Haavelmo, Koopmans, Klein, Arrow, Simon, Debreu, and Patinkin.

[11] Although Samuelson's book made an immediate impact, it took several decades (in the 1970s and 1980s) before game theory became a research project to be reckoned with within economic science.

Samuelson's book, more than any other single work in economics symbolises the new era in economics. Unlike von Neumann and Morgenstern's book which was a reflection of the latest formalising developments in mathematics, representing the new mathematics envy tendency in economics, Samuelson's chief influence came from the developments in physics, thus representing a step back in the direction of the physics envy of the nineteenth century - only that the type of physics he was imitating was the thermodynamics of late nineteenth century, rather than the mechanics of the earlier nineteenth century. On top of setting the standards of rigour, the concept of constrained maximisation he introduced became the economist's chief tool for the next several decades. Samuelson became the symbol of the new era also for another reason. His textbook *Economics*, published in 1948, replaced Marshall's and became the standard textbook for the new era.

During the 1940s the process of mathematisation and axiomatisation of economics was given further impetus by the war, which had both immediate and long-term implications, all in the same technical direction. So, it was the need to mobilise resources through the regulation of the economy in the context of military planning that increased the demand for the economists' skills and offered them the chance to apply their technical prowess, mostly in the areas of resource allocation and strategic decision making (Morgan and Rutherford, 1998, pp. 12-3). As Mirowski (2002) has shown, the war also had a big impact on economics through the militarisation of scientific research it brought about, leading to the development and use of advanced mathematical tools, what later became known as operations research, but also artificial intelligence, information theory and cybernetics, which were later on applied to economics leading to a new economic methodology (see also Boland, 2006, Rizvi, 2001: 217).

6. The Take Off

If the 1930s was the decade when the prelude of the formalist revolution was written and the 1940s the decade of its consolidation, the 1950s was the take-off period when the formalist revolution reached its climax. The pinnacle of this process was Arrow and Debreu's (1954) proof, for the first time, of the existence (but not uniqueness or stability) of a general equilibrium, and the re(in)statement of the Walrasian general

equilibrium system in a more mathematically formalised and rigorous way in Debreu's *Theory of Value* in 1959.

Some developments in economic methodology during this decade were of crucial importance in giving a further boost to the increasing abstractness and formalisation of economic theory. Here Friedman's highly influential 1953 essay "On the Methodology of Positive Economics" played a key role. According to Friedman, first, the role of economic theory is not to explain economic phenomena but to make correct predictions and, second, that the assumptions economists make should not necessarily be realistic as long as they make good predictions. Despite some heavy criticism coming mostly from economic methodologists, this methodological position was to play a major role in subsequent developments in economic thought, simply because it was convenient. In some sense it liberated economists who began to construct less and less realistic models using more and more sophisticated mathematical techniques without any circumspection. The emphasis began to be laid on the perfection of mathematical techniques and less on the explanation of economic phenomena.

The mathematical proof of the existence of equilibrium in a Walrasian system by Arrow and Debreu (1954) brought an end to a quest that started some eight decades back in the remote 1870s with Walras' work on general equilibrium. However, is did so at a huge cost. The necessary assumptions for this proof were simply extraordinary, including that "there are forward markets for every commodity in all future periods and for all conceivable contingencies and yet no one holds money as a store of value for more than one period" (Blaug, 1998, p. 11). So, the Arrow-Debreu proof evidently had more to do with mathematical logic than with economic reasoning as such.

The simple most important manifestation of this tendency is Gerald Debreu's book *The Theory of Value* (1959). In this work, the line of research in general equilibrium theory which started through the reworking of the Walrasian general equilibrium system in an axiomatic way by Schlesinger, Wald, von Neumann (all in Karl Menger's seminar), Koopmans, McKenzie and Arrow and Debreu, in the wake of Hilbert's Program in mathematics, reached a climax. Debreu's affiliation with Hilbert's Program came through the Bourbaki group. Back in Europe Hilbert's

Program in mathematics suffered a blow because of the proof of Gödel's incompleteness theorems in 1931 which "demonstrated the impossibility of setting up a completely consistent mathematical system" hence showing that Hilbert's program is untenable (Dow, 2003, p. 552). Despite this, the search for a more robust and rigorous mathematics based on axiomatics went on unabated until at least the 1970s. One of the best expressions of this continued quest was the formation of the Bourbaki group, the pseudonym of a group of mathematicians in France whose aim was to reconstruct mathematics on an axiomatic basis.[12] According to them, the role of mathematics is "to identify 'the fundamental structures' of operation in mathematics" and thus to construct an axiomatic theory as "a consistent set of definitions", or "an empty schema of 'possible realities'" (Ingrao and Israel, 1990, pp. 284, 285, Weintraub and Mirowski, 1994).

Debreu, being a student of Cartan, a member of the Bourbaki group, made no secret of his admiration of their work. According to him, "the new levels of abstraction and purity to which the work of Bourbaki was raising mathematics had won a respect that was not to be withdrawn" (quoted in Mirowski, 1993, p. 52). As he puts it in the Preface of his book, "The theory of value is treated here with the standards of rigor of the contemporary school of mathematics" (Debreu, 1959, p. x), according to which "an atomized theory has a mathematical form that is completely separated from its economic content" (Debreu, 1986, p. 1265). This took the form of Walras' general equilibrium theory which "in Debreu's interpretation … loses its status as a 'model' to become a self sufficient formal structure" (Ingrao and Israel, 1990, p. 286). The formalist revolution had reached its peak, as had the total detachment of theory from any claims to realism and real world relevance. "The objective was no longer to represent the economy, whatever that might mean, but rather to codify that elusive entity, the Walrasian system" (Weintraub, 2002, p.121). The cost of theoretical "rigour" and mathematical elegance was indeed immense.

[12] Diedoriné, Cartan, Weil and Mantelbrot were among them.

7. No ideology please we are economists?

Neoclassical economics and liberalism have been fellow travelers since the inceoption for the former during the marginalist revolution. This intimate relationship was, to begin with implicit in the inbuilt ideological biases of neoclassical theory favouring of free markets. What was implicit in the pre-war neoclassical economics was made explicit during the Cold War era through the attempts to build the explicit theoretical and philosophical foundations of political liberalism and western type democracy. This mostly took the form of rational choice theory. With rational choice theory the intellectual marriage between rationalism and liberalism, a journey that started during the Enlightenment, reaches a climax (Amadae, 2003).

The political and ideological climate during the interwar period and socio-economic developments such as the birth of the Soviet Union and the Great Depression in the West meant the climate was not conducive for a theory favouring free markets to dominate the scene. Even neoclassical proponents were skeptical of the power of free markets to deliver full employment and prosperity. This continued unabated in post-War Europe. In Britain, during this period, “collectivism, premised on Fabianism and Keynesianism, was the ruling orthodoxy of all parties and governments” (Cockett, 1994, p. 6). The so-called Golden Age capitalism was associated with Keynesian anti-cyclical intervention in the economy and the emergence of the modern welfare state.

Over the Atlantic, however, where the centre of gravity in economic science switched after the war, the ideological atmosphere was rather different. Having defeated Nazism and Fascism a new opponent was found in the face of their war allies, the Soviet Union. Although this war had military aspects to it, it was a war fought mostly at the ideological level. “In light of the Cold War ideological struggle against the Soviets, this enterprise of securing the philosophical basis of free world institutions was critical” (Amadae, 2003, p. 12). The ideological climate after the Second World War which was highly influenced, if not determined by, the Cold War and McCarthyism, played a pivotal role in this turn of events in economic science. This was done both directly through personal purges and the suppression of certain ideas, and indirectly through the direction of state related funding to specific kinds of research at the expense of others.

The name of the game for US administrators was to counter communism and the collectivist ideology. “Certain tendencies in economic analysis … were regarded as dangerous, wrongheaded even treasonous … The impact of McCarthyism … was profound and widespread … National Security concerns … played no small part in the enfeeblement of other intellectual traditions” (Bernstein, 2001, pp. 105-6). The most obvious target was of course Marxism because of its direct affinities with the communist ideology. Marxists and left wing economists more generally put their careers at grave risk (p. 106), but they were not alone in this. Keynes’s legacy, which was gaining more and more support even in the USA, was another target of McCarthyist attacks. The problem was of course that Keynes favoured government intervention and a strong state. The result was that anything to do with Keynesianism was associated with the collectivist ideology and a witch-hunt started which lasted throughout the 1940s and 1950s (Goodwin, 1998, pp. 56-62).

Recent scholarship has also brought to the fore the ways in which governments and in particular defense related agencies in the USA have exerted a direct influence in the construction of specific theories. Following the war, the military establishment in the US continued to have a direct role in the development of science and of economics in particular influencing decisively the way in which the latter evolved in the immediate post war period. This was done through the direction of funding to specific research programs. Thus most of the funding of the Office of Naval Research, for example, went to mathematical economists, Arrow and Debreu among them, because research in areas of mathematics and mathematical economics was considered more valuable to the objectives of national defense and security. In 1945 the Rand Corporation was founded by the US Air Force whose chief aim was to continue the scientific developments of the war, but also to counter the nuclear and ideological threat of Communism (Goodwin, 1998, p. 64, Bernstein, 2001, pp. 97-100, Amadae, 2003, ch. 1).

What is of direct interest for our purposes is the fact that Arrow’s *Social Choice and Individual Values*, one of the cornerstones of the ongoing formalist revolution and of rational choice theory which “arguably had an ideological use, since it provided an intellectual framework for opposing communism”, arose out of his involvement with the RAND Corporation (Backhouse, 2010, p. 145). Specifically, “Arrow was charged at RAND with determining a mathematical expression of Soviet

Union's collective utility function that could be useful for game-theoretic strategy computationsof nuclear brinkmanship" (Amadae, 2003, p. 85). In this direction, his main question was whether "it is possible to derive collectively rational group decisions from individual preferences?", to which his answer was that "collectively rational group decisions are logically impossible" (p. 83). This is Arrow's famous "impossibility theorem", which became the cornerstone of the defense of capitalism democracy against Marxism and communism. Granted all this, it is obvious that Arrow, in more ways than one is the child of Cold War, "a high level participant of the Cold War establishment" (p. 85). But Arrow's success was even greater than that. Because he showed the supremacy of western democracy over its rivals, using the "objective" tool of mathematics and rational choice theory hence becoming "one of the key creators of the intellectual tradition that would give shape to orthodox American economics during the Cold War period" (p. 85). So not only did Arrow furnish the philosophical underpinnings of post-War liberalism, he did so using the scientific tools of rational choice theory, hence becoming one of the protagonists of the formalist revolution and of post-War mainstream economics. In doing so, however, also brought ideology for the first time so explicitly at the heart of economic science under the veil of mathematical theory. As Amadae (2001, p. 12) puts it "in its guise as 'objective' or 'value free' social science it is difficult to appreciate the full impact of social choice, public choice and positive political economy for reconceptualising the basic building blocks of political liberalism". As Bernstein 2001, p. 247) puts it, "anti-communism was a fundamental part of the process that defined what was (or was not) scientific …". In fact, the more directly ideological the use of economics became, the more the need to present it as "scientific" and "objective". No other tool could serve this function better than mathematics, not least because of its prestige as a scientific instrument.

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