Arrow on General Equilibrium

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This note summarizes Kenneth Arrow's contributions to General Equilibrium Analysis; in particular, topics that he himself considered to be important are discussed. We use the Nobel Acceptance speech to identify such topics.

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1. Introduction

One of the Seven Wonders of the Ancient World was the statue of Colossus built on the island of Rhodes; this was a statue of the Greek God Helios and was built in 280 BC. The statue was 33 metres high (about as high as the Statue of Liberty in the US) and dwarfed everything not only around it but was also the tallest structure anywhere in those ancient times. It was destroyed in the earthquake of 226 BC and was never to be built again. Its supremacy gave rise to the word or phrase Colossus. Kenneth Joseph Arrow (23 August 1921 - 21 February 2017) and his contributions over his entire working life easily make him eligible to the title of Colossus of Modern Economic Theory; the influence of his work will remain far longer than the original
statue of Colossus of Rhodes. We present first, a short listing of his works before following the dictates of the Editors.

His main books, in order of their appearance:
1971 General Competitive Analysis (with F. H. Hahn), San Francisco: Holden-Day.
1981 Handbook of Mathematical Economics, Volumes 1-3 (Ed. with M. J. Intrilligator), Amsterdam: North Holland.
1984-85 Collected Papers
   I Social Choice and Justice
   II General Equilibrium
   III Individual Choice under Certainty and Uncertainty
   IV Production and Capital
   V Economics of Information
   VI Applied Economics
Each of the above volumes published at Cambridge, Mass: Belknap Press.

In addition to the above books, in 1972, he was the youngest recipient of the Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel, a prize shared with Sir John Hicks. To this date, he remains the youngest to have been awarded the prize. At the time of the award Professor Arrow was at the Harvard University and the citation mentioned that the award that year was for “their pioneering contributions to general economic equilibrium theory and welfare theory”. The field mentioned was “general equilibrium theory, welfare theory” and the contribution singled out was that he had “Made fundamental contributions to the renewal of the general equilibrium theory, work with welfare theory and work in the theory of social choice”. What this account fails to mention is that his mere presence
radiated a kind of an aura, which was backed up by his detailed knowledge on practically everything under the sun, his ability to think and speak rapidly at a rate which far exceeded that of normal humans; thus everyone felt intimidated by him.

We shall now confine attention to his contribution to General Equilibrium. However, Arrow writing about his own work and making our objective quite difficult to attain, has the following to say: “The central question in most of my work in economics has regarded, one way or another, the concept of general competitive equilibrium and its range of applicability, including the limits on that range.”¹ We shall of course not take the above literally! Following Arrow's Noble acceptance speech (Arrow [1974])², there are three main areas where Arrow's contribution to General equilibrium will remain definitive: the first is the Existence Proof, the second is the Fundamental Theorems of Welfare Economics and the third is the handling of Uncertainty in General equilibrium.³ We shall consider them briefly one by one; while Arrow himself contributed to the latter two areas first, we shall take them in

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¹ K. J. Arrow (2009), “Some Developments in Economic Theory since 1940: An Eyewitness Account”, The Annual Review of Economics”1, 1-16, beginning of Section 3 on General Equilibrium. In what follows, we shall refer to this as the Eyewitness Account.

² K. J. Arrow (1974), General Economic Equilibrium: Purpose, Analytic Techniques, Collective Choice, American Economic Review, 64, 253-72. The Section 2 of this contribution is titled the Hicks-Samuelson model of general equilibrium, and Arrow attributes his entire work in general equilibrium to this area. Hicks was awarded the Nobel Memorial Prize together with Arrow; it may be recalled. We may note that in his youth, Arrow was not really taken with the justly famous Value and Capital; although he says that the Hicksian volume did give him “a powerful orientation to economic analysis” when he encountered the volume in his youth; and we learn from his Eyewitness account, referred to earlier, that he had wanted to work on setting matters straight so far as this work was concerned, for his Ph.D. dissertation. He goes on to dismiss this as a ‘very foolish idea’ but his critical attitude towards the Hicksian configuration, is not hidden. He does say that “an uncritical attitude towards any work” must be seen as “a sign that the work was not very interesting”. All quotations are from the Eyewitness Account, Arrow (2009), p. 6-7.

³ In this assertion, it may occur to some to query why the contributions of Arrow to the area of Stability of Equilibrium did not merit mention. Arrow together with Hurwicz and others have exceptionally neat contributions to the area. Many of these are included in the collection Arrow and Hurwicz (1977) mentioned below. As to the silence on these contributions, one can only hazard a guess. Most of these contributions were very neat applications of Liapunov’s indirect method of solving a system of differential equations, by constructing a Liapunov function and demonstrating global stability whenever such a function could be constructed. This line of approach, to global stability was novel of course. But given the fact that these were satisfied in some special situations, the results were not found significant enough. It appears that Arrow did not think that his contribution in this area merited a mention.
the sequence we have mentioned.

Before we start, it should be pointed out that while it is only Volume II of the Collected Papers which is said to relate to General Equilibrium, the Volume does not constitute an exhaustive collection. There are many more papers on General Equilibrium in the Arrow and Hurwicz edited collection. In fact, as he himself noted and we pointed out earlier, generally speaking, many of the papers in the other volumes may also be classified as belonging to the same genre.

2. General Equilibrium Theory Pre 1954

What is General Equilibrium theory? I think it should be pointed out that the word ‘theory’ in the phrase ‘General Equilibrium Theory’ is perhaps wrongly used. General Equilibrium Analysis is better nomenclature. General Equilibrium method is about studying interconnections between markets; if one carries out any analysis where such interconnections are allowed and analysed, then one is carrying out a general equilibrium analysis. In case such interconnections are not being studied and one is confining attention to a single market in isolation, we have what is known as a partial equilibrium approach. In this sense, prior to 1954, anyone who studied economic systems where connectivity between markets was being taken into account, one was doing General Equilibrium Analysis. There were many writers who found that such interconnections were important. Of course the first person to highlight the difficulties that such interconnections raised was Walras (1874-77). But there were many who took it for granted that such interconnections are there and we need to address them. Two distinct specializations were followed.

Among the classical writers, Adam Smith, D. Ricardo, J.S. Mill, K. Marx, each had a theory of value; they were each interested in the determination of prices. Thus General Equilibrium analysis straddled across many schools of thought. However, their analysis proceeded by means of an assumption that there was only one primary factor; so that cost of production in terms of the single factor, usually identified with

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labour, solved the problem in its entirety. In their scope of things, demand played no role whatsoever. For example in the case of two goods, with a single factor, it is well known that the production possibility locus is a straight line. Once this is understood, it should be clear that it is the slope of this line which dictates what prices must be: demand has no role to play. In modern terms, we can use the structure of Leontief to write out the zero profit conditions to determine what the prices of the different sectors would be. If we take the simple Leontief Model with the input matrix \( A = (a_{ij}) \) where \( a_{ij} \) is the nonnegative amount of \( i \)-th good in unit output of \( j \) and \( l = (lj) \) is the amount of the single resource, labour, required to produce unit output of \( j \), we have from zero profit conditions in each sector the following equations, writing \( p \), \( w \), as respectively, the price vector and the wage rate:

\[
p(I - A) = w.l
\]

Clearly, under most situations, where \( A \) satisfied the productivity conditions, \( p \) would be uniquely determined in terms of \( w \) by the equations:

\[
p = w. (I - A)^{-1} l
\]

It would not matter if instead of the simple Leontief Model, we allow for some substitution among the processes of production in each sector. The famous Non-Substitution Theorem holds and we can get along without much ado. Notice in all of this, demand has no role to play. But value has been uniquely determined.

Alternatively, closer to 1954, Abraham Wald (1934-35, 36) went to the other extreme: what he had assumed amounted to assuming that the market demand originated from the maximization of a single individual or that there was just one person in the economy. What he had actually assumed was that “Weak Axiom of Revealed Preference held in the Aggregate”; something which may be ensured if the

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aggregate demand originated from the maximization of a single individual's utility function. Then Wald could not only show that there was an equilibrium but that the equilibrium was unique. Clearly the problem of determining value was solved once again. But both these approaches used fairly extreme restrictions.

The 1952 Meetings of the Econometric Society were to prove to be a watershed in the determination of value. Presumably work has been going on earlier and 1952 Meetings saw the presentation of two papers: one, a joint paper by Arrow and Debreu and the other, a solo effort by McKenzie. Both of them offered proofs of the existence of a competitive equilibrium. General Equilibrium Analysis had arrived and with a bang. Who got there first is a natural question. There has been considerable debate on this matter. For those interested in a blow-by-blow and fascinating account, see Düppe and Weintraub (2014)\textsuperscript{10}. However, in the Eyewitness account, Arrow (2009), page 9, third paragraph from the top, writes, “Lionel McKenzie, equally influenced by Nash, wrote the first proof of existence McKenzie (1954), followed shortly by Arrow and Debreu (1954)”.\textsuperscript{11} This acknowledgement was quite late in the day for McKenzie; for by then, Arrow in 1972 and Debreu in 1983 had received their prizes.

3. The Existence Proof

For the laity, the existence proof is all that's there to General equilibrium theory but that belief is totally erroneous. The centrality of general equilibrium to economic theory was noted by Schumpeter (1954)\textsuperscript{12}, when he described the defining of equilibrium through the Walrasian system of equations depicting the interdependence of markets as the ‘Magna Carta’ of economic theory. Please note that prior to 1954, there was no formally comprehensive “proof” that these set of equations had a solution or that it was possible to determine value of goods and services where demand played a role. So the entire Walrasian apparatus did not lead anywhere. It said what needed to be done but it was still not clear that we could end


\textsuperscript{12} J. Schumpeter (1954), History of Economic Analysis, NY: Oxford University Press.
up with the elusive values that we wanted to determine, if we followed the Walrasian formulation; except for two distinct extreme cases mentioned earlier. Surely there would be more than one person and equally surely, demand would affect prices.

For the sake of brevity, consider a standard Walrasian set-up or what is usually referred to as a private ownership economy: the fixed data consists of tastes, technology and initial holdings of commodities by consumers and from the participation in their firms’ profits; each consumer is a price taker. To simplify matters, the supply function for each firm, single valued function of prices (and of course the technology), is the profit maximizing response with positive entries as supplies and negative entries as demand for inputs. The consumers have two possible sources of income, from the sale of their initial endowments and from participation in their firm’s profits, given the prices; they maximize their preferences by choosing the best plan which consists of demands of commodities and supply of inputs. Assume for the moment that these are single valued too. Aggregating over consumers and firms we obtain the excess demand 

\[ Z_j(p_1, \ldots, p_n) = 0 \quad \forall j = 1, 2, \ldots, n \]  

(3.1)

It is also known from the time of Walras that these equations are not independent, due to the following relationship which exists for all \( p \) for which the above maximization by firms and consumers, is feasible:

\[ \sum_{j=1}^{n} p_j Z_j(p_1, \ldots, p_n) = 0 \]  

(3.2)

This equation (3.2) is important enough to be given a name viz., Walras Law. Consequently, the equations in (3.1) can define at most \( n - 1 \) variables: the relative prices obtained by choosing one of the goods, say \( n \) as the numeraire, or the unit of account.

Walras counted the number of equations and number of variables and assumed that there would always be solutions. Notice that this is not really a ‘proof’; it was more of a pious wish; there is also a difficulty that the functions \( Z_j(.) \) are unlikely to be linear functions because of their interconnection due to (3.2). So some strategy was
required to demonstrate existence. According to Arrow, this impetus came from Nash’s proof of the existence of a non-cooperative game and the use of the Kakutani fixed point theorem and each sought to apply the Kakutani theorem to their own problems; a part of this may well be true. In fact, an additional problem needs to be mentioned here.

Arrow and Debreu were working independently of one another and exchanged papers and provided comments to each other, when they discovered that there was a problem; the very thing which they had used to simplify their excess demand to be functions (single valued) showed that excess demand functions may not be well defined when prices go to zero. In particular, if the underlying preferences and technology exhibit strict convexity, then this distortion will be present. To guard against this, they took the restriction of ensuring that incomes do not approach zero when prices go to zero by ensuring that the initial stock of commodities lie within the interior of the consumption set. With all these preliminary remarks out of the way, the Arrow Debreu method may now be described.

Instead of seeking the solution to (3.1) directly, the Arrow-Debreu procedure was to carry out the following steps:

1. associate a generalised game with the economy at hand;
2. proving that there is one equilibrium of this generalised game;
3. proving that at this equilibrium for the generalised game, all markets clear.

A game is specified by choosing the players, their strategy sets, their decision variables and their payoff functions. Given the economy as specified earlier, the players for this generalised game are the consumers and the firms and one additional fictitious player, the auctioneer. The auctioneer chooses the prices of the commodities; firms choose their supplies by maximising their profits; the consumers choose quantities they wish to trade; if there is balance in every market then the game finishes; otherwise, the auctioneer increases the prices of good in excess

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13 But we know from personal conversation, that McKenzie read the Kakutani theorem in the pages of the Duke Mathematical Journal; he was at Duke those days and realized that he had the tool to apply to this problem.

14 I may mention here that while teaching, I too figured out an alternative way of handling this same problem and it is reproduced in my book, Mukherji (2002), An Introduction to General equilibrium Analysis, Oxford University Press, Delhi.
demand ($Z_j > 0$) and lowers the price of goods in excess supply ($Z_j < 0$) and the game is played out. With enough adequate structure on various aspects, the procedure is carried out and we have our existence theorem.

Duffe and Sonnenschein (1989)\textsuperscript{15} describe how this approach is amenable to generalizations to cover for many types of complications and therefore is a very useful approach. But the other approach to appeal directly to excess demand functions which was the approach adopted by the others who ‘also ran the race’\textsuperscript{16} was also the method adopted by Arrow himself in (1974) while delivering the Nobel Acceptance speech and which is referred to earlier as Arrow (1974).

We complete our discussion of this section by addressing ourselves to a criticism often made by those who accuse the entire tribe of general equilibrium analysts of being affected with a maths fetish, needlessly using high powered mathematics and distracting attention from so-called fundamentals. The charge was frontally answered by an elegant demonstration by Uzawa (1962)\textsuperscript{17}. The paper showed the equivalence between the two results: the existence of competitive equilibrium and Brouwer’s fixed point theorem. That this can be extended to cover the Kakutani Theorem as well, may also be demonstrated\textsuperscript{18}. Thus, to prove the existence of competitive equilibrium we have to use some result which is powerful enough like a suitable fixed point theorem and thanks to Uzawa, we now know that there is no escape from that eventuality.

4. The Fundamental Theorems of Welfare Economics

Around the time that Arrow was trying his hand at what came to be called the famous Impossibility Theorem of Social Choice\textsuperscript{19}, he was also trying to extend the

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\textsuperscript{15} Arrow on General Equilibrium, Journal of Economic Literature, 27, 565-598.
\textsuperscript{17} Walras's Existence Theorem and Brouwer's Fixed Point Theorem, Economic Studies Quarterly, 13, 59-62.
\textsuperscript{19} Although Arrow referred to this as a General Possibility Theorem.
scope of the Fundamental Theorems of Welfare Economics. These results go back in
time and methods showing the equivalence of Walrasian equilibrium with an
optimum using Calculus can be traced to Lange (1942)\textsuperscript{20}. There are two parts of the
Fundamental Theorems: the First which says that every competitive equilibrium
induces a Pareto Optimal state; this is called the First Fundamental Theorem of
Welfare Economics. The Second Fundamental Theorem of Welfare Economics
asserts that for every Pareto Optimal State, there is a competitive equilibrium which
supports that Pareto Optimal state after possibly a redistribution of endowments. But
of course there are qualifications.

The modern versions of these results are due to Arrow (1951) and Debreu (1951)\textsuperscript{21}. Arrow realised that the calculus methods ruled out corner optima but that corner
optima and equilibria possessed the same properties of interior optima and equilibria
most of the time and to make an attempt to include such corner configurations, new
tools, more basic than the use of calculus were required. As he said “elementary
theorems for convex bodies” would do the trick! Here a very significant point of
difference between the two Fundamental Theorems emerges: one that was apparently
not noted in Arrow (1951).

So far as the First Fundamental Theorem is concerned, no assumption of convexity is
required and the argument is as simple as an argument can be; yet this result is one of
the most basic and perhaps the most significant one in economic theory. The crux of
the matter is the crucial observation that a ‘better’ or preferred bundle must cost
more. The essential fact is that convexity is not required nor is continuity needed.\textsuperscript{22}
Simple proofs serve the purpose of identifying exactly what things may go wrong.
For example, what we have not said is that the crucial step actually uses an
assumption that quantities involved are finite; but in simple contexts like Cass and

\textsuperscript{21} K.J. Arrow (1951), An Extension of the Basic Theorems of Classical Welfare Economics, in J.
Neyman, Ed., Proceedings of the Second Berkeley Symposium on Mathematical Statistics and
Probabilitiy, Berkeley, U. of California Press; and also Debreu, G. (1951), The Coefficient of Resource
\textsuperscript{22} M. Majumdar forthcoming paper, Mathematical Economics: Tools and Problems has a superb
discussion.
Yaari (1966)\textsuperscript{23}, the result breaks down on account of there being an infinite number of agents (across periods) and we cannot say that one side is larger than the other, because both are infinite.

The Second Fundamental Theorem simply put can be explained in the context of the two-agents two-goods exchange context thus\textsuperscript{24}: consider the Edgeworth Box; consider an interior Pareto optimum state; i.e., an allocation which lies on the contract locus and is not on the boundary of the box, where indifference curves are tangential to one another; choose the common slope of the indifference curves and choose that point as the initial state; and you have a zero trade Walrasian equilibrium. And that is the result. The second result however requires strong properties of convexity of preferences and also the convexity of the different sets involved. For instance, in our discussion above, the basic assumption is that the price line supporting the two indifference curves keeps the indifference curves on two sides, a convexity assumption. Arrow considered in detail the case of a single household, which allowed him to use the separation theorem to separate the transformation set from the set of preferred bundles; he also seized on the example of a Pareto optimum on the boundary which can never be a Walrasian equilibrium. Arrow in his (1951) paper and in his Nobel acceptance speech which appeared in the American Economic Review (1974), gave a lot of emphasis to the Second Fundamental Theorem and to separation theorems for convex sets; the First Fundamental Theorem was mentioned as an add-on, a mere by product of the analysis and noting that no convexity was required; the last, as we had remarked earlier, was not noticed in the (1951) contribution\textsuperscript{25}.

The appeal of the two Fundamental Theorems has been to two different classes of economists. The free marketeers thought that the First Fundamental Theorem was important and the appeal of the competitive equilibrium lay precisely in this result; whereas the socialists, who wanted to choose a particular optimal state and then

\textsuperscript{24} The following, if I recall correctly, was pointed out to me by Dipankar Dasgupta during discussion, many years ago.
decentralize that state by computing prices through a planning exercise, found the Second Fundamental Theorem to be of greater importance. With the decline of socialism and planning exercises, the importance of the Second Fundamental Theorem has diminished. Maybe, not for Arrow himself as his Nobel acceptance speech seems to indicate; was this his socialism coming to the fore?

5. Uncertainty and General Equilibrium

Given Arrow's training as a statistician under his supervisor, Harold Hotelling, he was particularly well placed to make his forays into the introduction of uncertainty into consumption theory. As Duffe and Sonnenschein (1989) note, “none of the key ideas in the Role of Securities in the Optimal Allocation of Risk Bearing\(^\text{26}\) call for a new proof. The achievements are entirely conceptual and interpretational”. In spite of this the contributions made here are perhaps the most influential that Arrow has made to equilibrium theory, note Duffe and Sonnenschein. This coming from two such eminent scholars needs to be considered carefully. The stated objective was to introduce how the standard theory of consumption under certainty could be expanded to take into account uncertain situations \(^\text{27}\).

The introduction of contingent commodities achieved the first step. These commodities are commodities associated with the state of the world. For instance if there is a single commodity corn and two states of the world rain or shine then there are two commodities (prior to the uncertainty of the state of the world being resolved), corn with rain \((c_r)\) or corn with shine \((c_s)\). After the uncertainty is resolved, there is just one commodity of course. Consider the application of the standard Edgeworth Box story of two agents with an endowment of these two


\(^{27}\) I do not dwell on Arrow's contributions on measuring the attitude towards risk which lead to the various measures of risk aversion; nor do I spend time on the very interesting contribution of Arrow and Hurwicz on handling the situation of complete ignorance, when the Expected Utility Theorem cannot be used since the probability distributions are not known. The Yrjo Jahnsson Lectures. 1963. Kenneth J. Arrow, Aspects of the Theory of Risk-Bearing and K. J. Arrow and L. Hurwicz, An Optimality Criterion for Decision Making Under complete Ignorance that appear in Arrow and Hurwicz (1977) mentioned earlier, are classic and crucial contributions.
commodities depicted by a point say $W$ in the box where the dimension of the box depicts the total amounts of $c_r$ and $c_s$ available. Each agent has indifference curves over different combinations of $c_r$ and $c_s$, just as any Edgeworth Box demonstration proceeds, and there is no a priori reason to expect that the indifference curves through $W$ be tangential to one another at $W$; a straight line through $W$ depicts a budget line and trading opportunities are depicted just as usual in such cases.

If the line through $W$ is tangential to indifference curves of the two agents say at $E$; then the line $EW$ demonstrates the price of $c_r$ to $c_s$ which achieves an efficient allocation of risk bearing to use Arrow's terminology. If such trades in contingent commodities do not take place, they miss the opportunity to insure themselves against the vagaries of the state of nature.

With $n$ commodities and $M$ states of the world, there are $nM$ state contingent commodities and agents can trade in them. For instance the price of the delivery of an unit of good $j$ in state $K$, is denoted by $p_{jK}$ and the vector of all prices of state contingent commodities may be then written as $p = (p_{jK})$ and allocation to agent $i$ may then be denoted by $x^i = (x^i_{jK})$ and so one may then proceed to look at efficient allocation of risk bearing, by looking for an equilibrium and using the First Fundamental Theorem. But as Duffie and Sonnenschein (1989) note, Arrow looks for efficient allocation of risk bearing and then constructs prices which will support this efficient allocation which is by way of appeal to the Second Fundamental Theorem. There is nothing new, in one sense. In fact, Debreu (1959) in the Theory of Value, not only added state of the world, but also time and location to each commodity and obtained a model formally identical with the certainty version.

The problem of so many markets is of course mindboggling and quite far from reality. There is one other idea that Arrow introduced, sometimes referred to as an Arrow security, which pays say 1$ if a particular state of the world occurs and 0 if it does not. Every risky financial contract, a stock or bond or even a house is a very complex security made up of a bundle of Arrow securities. Thus Arrow securities are the building blocks used to deal with risk and uncertainty. While this aspect is widely discussed in the literature, in Arrow (1974), there is no mention of this; rather there is a discussion of the information content of decision makers in uncertain situations. Assuming that every one has the same information is difficult and Arrow talks about the allocational inefficiencies which might arise and which are important in diverse
areas: he does mention race relations and climate change. And Arrow in (1974) points towards Radner (1968)\textsuperscript{28} for a more satisfactory treatment of uncertainty in general equilibrium.

6. Arrow on Socialism, Ethics and Concluding Remarks

In the little known document “A Cautious Case for Socialism” in the Fall of 1978\textsuperscript{29} Arrow takes up the question of whether socialism can co-exist with democracy\textsuperscript{30} or whether capitalism is necessary for democracy. And the person skilled in constructing counter-examples, mentions immediately Nazi Germany, Fascist Italy and Franco’s Spain as clearly showing that capitalism can flourish in dictatorial regimes. He discusses his own preference for cooperation rather than competition and his discussion of Gandhi and the principle of non-violence deserves to be read. In particular, one has to be struck by how perceptive his remark is, that for the principle of non-violence to make a dent, a necessary underlying assumption has to be the common humanity of the ruler and the ruled.

Arrow began with a firm belief in Socialism; growing up during the Great Depression, this was perhaps not entirely unexpected; however, given the example of Milton Friedman, also growing up in the same period, one can see that being socialistic was not inevitable. But he proceeds to debunk his own ‘naive’ beliefs as he called them. But still he clearly argues against the views of Hayek who firmly held that increasing government expenditure or strengthening government intervention or other social experimentation will lead to an irreversible slide to serfdom. He ends his essay on Socialism with the stirring words, “Experiment is perilous but it is not given to us to refrain from the attempt”.

As a part of the Oral History Program at Stanford, Arrow was asked how he came to be interested in Ethics. In answer, Arrow spoke uninterrupted, as if he was reading

\textsuperscript{28} R. Radner (1968), “Competitive Equilibrium under Uncertainty.” Econometrica, 36, 31-58. In this connection, Majumdar in the paper mentioned earlier has an interesting discussion.

\textsuperscript{29} K. J. Arrow (1978), A Cautious case for Socialism, Lecture delivered as the Third Lionel Trilling Seminar, Academic year 1977-78 at the University of Columbia, published in Dissent.

\textsuperscript{30} I am using the author’s prerogative to diverge from General Equilibrium since I feel it is important to see the Master’s mind at work on such a topic. Besides, we are not that far from General equilibrium in such discussions.
out from a prepared typescript; the edited typescript ran into 13-14 pages. Arrow began by saying, “To say that I am interested in ethics is probably just to say that I am a human being. You are brought up full of ethical concerns; these things are part and parcel of life. The real issue is whether you think of ethical concerns rather than accept them.”

He has thought deeply about things; for instance he wonders since 2/3 of the public expenditures in the US Government are for the production of private goods, why is there hardly any argument about that except at the margin. He has been concerned about climate change and he clearly supported a strong social obligation to be concerned for the future generation. Matters cannot be left to individual motivation, he admonished. Questions such as how does a consideration of a person's welfare affect another, concerned him deeply. He worried too, about the role of the family, something which has traditionally not been discussed in economics because it was never considered problematic. But now with society undergoing rapid transformation, this is something that needs to be considered. He would have liked Economics to be a much broader discipline. He commented that we in the profession seem to be really concerned about individual irrational behaviour whereas social interactions are not studied and he found this unacceptable. It can be clearly seen that in his absence the entire profession has lost one of its major problem solvers and we have been left to fend for ourselves as best as we can.

Finally among his main collaborators, G. Debreu, L. Hurwicz and F. H. Hahn, the first two received the Nobel Memorial Prize; among his doctoral students, J. C. Harsanyi, Michael Spence, Roger Myerson and Eric Maskin received the prize as well. Arrow himself would like to add the name of James Mirrlees to this list, since while visiting Oxford not only did he supervise but he also ended up examining the dissertation that Mirrlees submitted. If we take stock of everything that he has written and left his mark on, how many Nobel Memorial prizes can he claim? Most commentators would easily give him an additional 3 or even 4. Given his work on climate change, some may even vote him for the Peace Prize as well: he would certainly be more deserving than some of those who have been awarded on this

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count. Surely by any account it is a fantastic, stupendous record of academic activity. And as we said at the outset, wholly deserving to be called the Colossus of Modern Economic Theory.