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The Role of Information in Economics

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1. Introduction: The Big Question

The Italian title of this talk may be more accurate. As I understand it, «Il ruolo dell'informazione nell'economia» could be translated as "The Role of Information in the Economy" — that is, in the economic system. But it could also mean "The Role of Information in Economics" — that is, the importance to the study of economics of understanding better how information is used and disseminated in the economy. I shall indeed say something about the use of information in the economic system. But I shall say rather more about how much the study of information has recently added to our understanding of what economic systems are possible. This is largely because economics is at last paying attention to who knows what, and when they know it.

One of the most fundamental questions in economics is   , "How should the economic system be organized?" Should there be central planning, or capitalist free enterprise, or labour-managed firms, or production co-operatives? Should national and international capital markets be freer, or more tightly regulated? Should there be an extensive welfare state supported by large tax revenues, or more privately funded health and education services? What should be done about third world debt — or, indeed, about that of some countries in both the "first" and the "second" worlds? Or about the poverty and unemployment which still plague so much of the world? Can we reform the world's economic system in order to relieve the apparently irresistible pressure of human population on the environment and on the earth's biological resources, such as its forests?

I shall answer none of these pressing questions. But I shall not give you wrong answers either. This may be an improvement over some economists who seem to think that markets can be relied upon to solve everything. And an improvement over many non-economists, who often rush in with proposals which fly in the face of economic reality. The purpose of this lecture is rather to give you some idea of why economic reality is so complex — more complex, perhaps, than most economists who give policy advice seem ready to admit. I shall also argue that much of this complexity comes about because of the need to worry about the inevitable dispersion of information among participants in the economic system, no matter how well designed that system may be.

2. Pareto, Barone, and Hayek

Many in this audience have devoted far more time than I have to the diligent study of Vilfredo Pareto and Enrico Barone's works. You will appreciate far better than I the important role which they had in early discussions of economic systems and in the branch of the discipline which came to be known as "welfare economics" — meaning, of course, the study of how

economic systems can be designed to promote human welfare, rather than just the study of welfare programs of public assistance.

Pareto (1906) and Barone (1908) were able to demonstrate how an optimally functioning centrally planned economy would essentially mimic a market economy — see also Kirman (1987). Optimality requires, for instance, that each consumer's marginal willingness to pay for a good should be equated to its marginal cost of production, and that other similar marginal conditions which would arise in a perfect competitive market economy and which are very familiar to economists should also be satisfied. Friedrich von Hayek chose to include in his volume entitled *Collectivist Economic Planning* — an English translation of Barone (1908). There Barone argued that it seemed much easier in principle to have markets co-ordinate the economy through price signals than to have a centralized bureaucracy determine everything. No doubt this appealed to Hayek. Indeed, in those days it could take a week of intensive effort by human computers to invert numerically even quite a small matrix. So the problem of calculating an optimal plan would clearly be unmanageable. This made market economies seem preferable because they appeared to require much less central processing of information. In effect, a market system could function as a kind of "parallel processing" computing machine for both calculating and putting into effect an optimal allocation of goods, services, resources, labour, etc. in the economy.

3. Formal Models of Information

Barone and similar minded economists were working in a world without modern game theorists or even decision theorists. Frank Ramsey (1926) and Bruno de Finetti (1937) had not yet begun their explorations of decision-theoretic subjective probability. But the most important idea in representing information formally in economics originates in the book by John von Neumann and Oscar Morgenstern (1944). One of their many contributions was the idea of representing information by means of a partition of possible states of the world into events. Things about which somebody may be uncertain, such as the weather now in different parts of the world, are represented as states of the world. Most people in Milan know the weather now in Milan, but not in London, or in San Francisco. Their information permits them to partition the set of possible states of world weather into different events, according to the weather in Milan. Two states will be in the same event of this partition if and only if they involve the same weather in Milan. Some people in Milan who do know the current weather in London will have a rather finer partition into smaller events, because two states will be in the same event of their partition if and only if they involve both the same weather in Milan and also the same weather in London. Those in London who know only the weather there will have a coarser partition, with two states in the same event if and only if they involve the same weather in London.

This powerful partition model allows differences in individuals information to be represented. People in London have a different information partition from those in Milan. It also allows changes in information to be modelled. After all, we all learn more about the world as time progresses, though we may also forget more than we should of what no longer seems relevant or important. In addition, this partition model helps explain how information permits adaptation to changed circumstances. Somebody leaving London or San Francisco to come to Milan without knowing the climate here has to be prepared for more eventualities than the local expert. If the Milan climate were different, the local expert would know it. Indeed, if a person is unable to distinguish two different states of the world because they belong to the same event of

his information partition, they are constrained to perform the same action in those two states. Whereas somebody who knows the difference has the opportunity to adapt. To take a more economic example, suppose some traders on the stock exchange have inside information that a particular firm is likely to be taken over. Their information partitions permit them to adapt their trading strategies to the likely date and offer price for this takeover. They have the information necessary to earn extra profits at the expense of outsiders who lack that information and so are forced to pursue less refined trading strategies in the stock of that firm.

4. Team Decision Theory

For many years after von Neumann and Morgenstern had created a language for describing different individuals' information, economists made very little use of it. A major exception was the development of a theory of "teams" by Jacob Marschak (1955) and Roy Radner (1962) — see also Marschak and Radner (1972). Players in a team have a common objective but may have different information. What rules should they follow in order to promote their common objective? What information should they communicate to each other, especially when communication is costly or time consuming? In meteorology, for instance, to what extent can information be collected from weather stations and satellites all over the world and then pooled in an effective way to improve weather forecasting everywhere? In economic systems, can prices communicate information effectively enough to allow consumers, producers, bankers, etc. to co-ordinate all their plans? These were the main questions which this theory addressed.

Except in time of war, weather services all over the world have more or less the same objective of improving weather forecasting everywhere. Because prevailing winds in more northerly latitudes tend to come from the west, it is true that European countries are likely to benefit more than North American countries from extra information about weather conditions in the Atlantic Ocean, and the reverse for weather conditions in the Pacific. Perhaps a few perverse farmers might wish that the weather service in their country did not provide information of use to competing farmers abroad. On the whole, though, international meteorological communication may indeed be viewed as a team decision problem. The same is rarely true of economic systems, however. Different participants in the economic system have widely differing objectives, especially when decisions affecting the distribution of income or wealth are being considered. This forces us to go beyond team decision theory into the fields of game theory and incentive compatibility.

5. Incentive Compatibility

Leonid Hurwicz was one of the first to suggest that economic systems should be considered as processes for allocating resources, and that it was not always enough just to consider the allocation which results from this process. Hurwicz (1960) also took the important step of representing resource allocation processes as involving the exchange of messages. His key contribution, however, was to introduce in the early 1970s the strategic ideas of game theory into the study of economic systems, and to marry these ideas to the information problems which arise in teams — see Hurwicz (1972, 1973). Specifically, suppose that an economic system were set up as a team decision problem, relying on individuals to provide each other with all the information needed to produce an optimum for the economy as a whole. Then individuals might well be acting in ways which run counter to their own interests. Trade secrets would not exist,

since they would be given away to anybody who could make good use of them. Someone with inside information about a companys prospects, rather than trying to make a profit for themselves first, would pass it on immediately, if that were desirable for society as a whole. Nor would this deter useful innovation, because everybody would only be interested in promoting the common goals of all society. If only …!

Instead Hurwicz recognized that individuals might well wish to withhold information. Or that they might be able to gain by creating ambiguity or even by being deliberately deceptive. Hurwicz pointed out the need to consider what he called "incentive compatible" mechanisms for resource allocation. These recognize individuals incentives to behave in the economic system in just that way which maximizes their own interests. In other words, the economic system has to be regarded as a complicated strategic game, with many participants playing against each other and reaching some kind of equilibrium. The only truly feasible economic allocations are those which can be reached as equilibrium outcomes of some incentive compatible mechanism.

As Hurwicz himself certainly recognizes, a few earlier or contemporary writers had also considered similar strategic problems. Unlike Hurwicz's consideration of general economic environments, however, these other writers considered incentive compatible mechanisms only in special cases. Thus William Vickrey (1961) had an early and profound study of auctions in which each potential bidder has private information affecting what he himself is willing to pay. Around the same time as when Hurwicz was writing on incentive compatibility, Ted Groves in his 1970 doctoral dissertation began to consider the question of how to get team members to pursue their team's objective when they each have their own individual interests to be concerned about — see also Groves (1973). Clarke (1971) addressed the problem of determining the efficient provision of public goods when each individuals willingness to pay for them remains as private information.

In the last twenty years, the literature on incentive compatibility has become truly enormous. It has permeated into almost every branch of economics. From now on I shall concentrate on Hurwicz's original question, as well as Pareto and Barone's. That is, I shall reconsider the problem of devising a good economic system. The important difference from Pareto and Barone is the recognition that, when information is dispersed in the economy, only incentive compatible economic systems should be considered. All others are vulnerable to manipulation.

6. Public Finance in Continuum Economies

I have already mentioned the early work on the efficiency of complete competitive markets and the apparent desirability of having a socialist economy mimic a competitive market economy. Most of this work, with the possible exception of that due to Pareto, did little to discuss important concerns of public finance such as distributive justice, public expenditure and taxation, or the treatment of what economists call "externalities". Where these concerns were addressed at all, there seemed to be an implicit presumption that distributive injustice could be cured by direct redistribution from rich to poor. And that public goods could have individualized "Lindahl" prices attached to them, so that each individual pays what the public goods are worth to him, just as if the goods were private after all. Such prices could then guide the economy toward the proper provision of public goods, as in Paul Samuelson's (1954, 1955) analysis. Externalities could then be treated in a similar manner, with individualized Lindahl prices

determining, for example, how much total pollution is allowed, and Pigou taxes being used to determine who is allowed to contribute each unit of that total.

In real economies, willingness to pay for public goods is typically private information. Samuelson mentioned the "free-rider" problem, with individuals tempted to understate their true willingness to pay in the expectation that this would have little effect on public good provision, but would greatly reduce what they were expected to pay. Hurwicz's work pointed to the incentive problems which arise even in economies where only private goods are being distributed through perfectly competitive markets. This incentive incompatibility of market allocations arises when individual traders have the power to manipulate prices in their own favour by acting as if they were only willing to trade less than they really are. With enough traders, however, this power would become negligible, as demonstrated in the work of John Roberts and Andrew Postlewaite (1976). Yet if one thinks in terms of individualized Lindahl prices for public goods, the free-rider problem arises because each individual would be a single monopsonistic buyer of his own version of each public good, and this power may not diminish as the number of individuals becomes large.

It turns out that incentive problems are pervasive. In public finance theory, optimal redistribution in an economy where everybody has known skills might well fit Karl Marx's prescription, "From each according to their ability, to each according to their need." Realism, however, requires recognizing that skills are not known. This seems to have induced a modern revision, so that now many socialists suggest "to each according to their work" instead of "to each according to their need". The point is that payment by work seems to be the only way of getting most people to use all their skills. China, for instance, has been trying to abandon its "iron rice bowl" as incentive incompatible.

In fact the link between public finance and incentive compatible mechanisms remains an area of active research. One case where general results are easy to derive and so relatively complete is when there is a "continuum economy" — meaning an economy with a continuum of agents. This requires that there should be one agent for each real number in the range between 0 and 1, and so infinitely many people. Of course, this cannot be literally true. But a continuum economy is a useful mathematical abstraction introduced by Robert Aumann (1964) to represent the idea that each agent has negligible power, just as each particle in statistical mechanics has negligible mass. Werner Hildenbrand (1974, 1982) has thoroughly investigated the mathematical question of when it is legitimate to use the continuum economy as a convenient approximation to an economy with a very large finite number of agents.

It is fairly straightforward to show that lump-sum redistribution of initial resources is generally incentive incompatible in a continuum economy. Some individual generally has an incentive to manipulate the redistribution mechanism by claiming to be slightly more deserving than he really is. The benefit of doing this is obvious: he will receive a slightly higher lump-sum subsidy, or be required to pay a slightly lower lump-sum tax. But there is also a cost, because the individual will receive the consumption bundle of that slightly more deserving person, rather than what the individual himself would want if he were free to spend the extra income as he wished. Nevertheless, the net benefit is usually positive for some individual, which is enough for incentive incompatibility. Only by basing lump-sum redistribution on observable and unalterable characteristics can this problem be avoided, except in special cases — see Hammond (1979, 1987), Champsaur and Laroque (1981, 1982), and Champsaur (1989).

So the optimal lump-sum redistribution of orthodox welfare economic theory turns out to be impracticable because we lack the information to put it into effect. Moreover incentive incompatibility tells us that individuals cannot be relied to provide that information willingly. This implies that commodity and income taxes, as considered in the work of Peter Diamond, James Mirrlees, and many succeeding public finance theorists, really are the best that is possible in most economic systems — see Diamond and Mirrlees (1971) and Mirrlees (1971, 1986). Orthodox public finance theory has regarded these taxes as distortionary, and has even set about measuring the "excess burden" or "deadweight loss" which such taxes are alleged to cause. The measurement involves working out the total gain to all consumers from abolishing distortionary taxes and replacing them with lump-sum taxes in a way which makes all consumers better off. However, the new lump-sum taxes have to vary for different individuals, depending upon their tastes, and so are unlikely to be incentive compatible. So the distortions are really illusory.

Of course, some limited lump-sum redistribution of wealth may be incentive compatible. The social security and welfare systems of most rich nations treat retired senior citizens far better than unemployed teenagers. Some poor nations have practised major redistributions of land in the past, and a few may yet have land reforms in the future. Unanticipated currency reform has often had intended redistributive consequences. But severe limitations remain. Poverty persists even in rich nations for many reasons, but at least one is that it seems practically impossible to target welfare programs only at the deserving poor. Then politicians are reluctant to be seen subsidizing a few scroungers, even if there is no other way to aid all those who genuinely need help.

7. Incentive-Constrained Pareto Efficiency

The constraints which incentive compatibility places on feasible wealth redistribution also make a big difference to welfare economic theory. For instance, they completely change the proper notion of Pareto efficiency to "incentive-constrained" Pareto efficiency. To show that a particular allocation is Pareto inefficient, we must find a new economic system which is not only feasible and makes everybody better off, but which is also incentive compatible. Pretending that we will be able to peer behind the curtain to discover information which is private is only to delude ourselves. Before the economic system can use any piece of private information, the person in command of that information must somehow be induced to reveal it, even though the form which this revelation takes may actually be very indirect.

When one understands the limits to feasible wealth redistribution, the familiar textbook link between Pareto efficient and market allocations is almost completely severed. Virtually every allocation on the Pareto frontier of orthodox theory is incentive incompatible; virtually every incentive-constrained Pareto efficient allocation of the new theory requires some interference with markets. Actually, it is just conceivable that the link could be re-established, but to do so would involve devising "perfected" markets, as I like to call them (see Hammond, 1989b). Such markets would be for options contracts of a form far more complicated than anything which has yet been dreamed up even in Chicago, either by a Professor of Economics (or of Law) at the University of Chicago, or by an enterprising market maker on the floor of the Chicago options exchange. Above all, there may have to be an infinite set of possible options available to the purchaser of some of these contracts. Also the usual linear pricing, requiring that you pay the total value of all your contracts at a fixed vector of prices, is nearly always inapplicable. Doubling the size of your contract could triple the cost.

8. Markets as Constraints

I have argued that dispersed information implies that all feasible allocations, including all market allocations, must satisfy incentive constraints. And that markets on their own are rarely able to allocate resources optimally in the presence of these incentive constraints. Why then do markets remain so pervasive? Are current trends like that toward market liberalization in centrally planned economies just dreadful mistakes?

To begin answering these questions requires, in my view, a totally different understanding of the role played by markets in most economic systems. The incentive constraints examined by Hurwicz and his successors tell only part of the story. These incentive constraints only concern what one might call the "official" economic system. Yet the world presents us with many obvious examples of "informal" or "underground" economic systems, including black markets, tax evasion, corruption, smuggling, etc. These involve transactions which are kept hidden from the eyes of officialdom, such as tax inspectors, regulators, customs officials. To the extent that the underground economy cannot be controlled, or can only be controlled at great expense, it limits the allocations which the economic system can produce. Sometimes this may not matter much. If farmers get their teenage children to help them out at harvest time during school holidays in exchange for tax-free pocket money, that seems to benefit everybody concerned, including the consumers of cheaper food. If workers with skills sell their services to friends in their spare time in exchange for cash, that is no doubt tax evasion, but again the benefits would often seem to outweigh the costs. Where there is an extensive, cumbersome, and inefficient bureaucracy, the informal sector may even become the only way for many people to survive. This may be the case in Peru, to name but one example, where I have heard it said that the informal sector constitutes just over 60% of the total economy. This, of course, makes it very hard for the Peruvian government to pay off its extensive debts, which may actually be all to the good of the world as a whole.

Not only unofficial markets serve as constraints, however. Consider tax harmonization within the European Community after 1992. There is not much reason to think that tax harmonization will actually produce a better allocation of resources. What is clear is that people will go on buying commodities where they are cheapest. The experience of the United States, where different states have markedly different rates of taxation, may be instructive. Some shops just on the wrong side of a tax border will become much less competitive. Mail order firms may flourish. New market opportunities will constrain the powers of national governments to raise tax revenue on purchases by their own citizens. For similar reasons, one also expects some capital and some skilled multilingual labour to move to those countries whose tax system treats them most favourably. But insisting on compete tax harmonization in order to avoid such problems seems to me quite excessive.

So market forces constrain economic policy. Sometimes bad unofficial markets constrain good policy. Examples are the illegal trade in narcotic drugs, armaments, and stolen goods, or where tax evasion becomes so widespread that a largely benevolent government becomes unable to fund worthwhile public expenditure on health, education, etc. Sometimes good unofficial markets mitigate the ill effects of an unrepresentative or incompetent government, or one which has had bad policies thrust upon it by a foreign power, an international agency, or just some foreign bankers. And of course markets help to limit all abuses of power, be they by governments or by private monopolies.

9. Imperfect Capital Markets

Dispersed information can make it difficult to suppress markets. It also creates difficulties for some markets to function at all. Kenneth Arrow (1963) discussed this in connection with insurance and medical care. George Akerlof (1970) used dispersed information to explain the thinness of markets for second hand cars and for loans in the rural parts of developing countries. Failures in credit markets seem especially important. They suggest that static economies, in which it is assumed that everything happens only in the present, really are very different from sequence economies in which the future matters as well. They also suggest to me that macroeconomists have been looking for foundations where microeconomists have yet to finish surveying the land to be used as a building site, since microeconomists have not yet done a good job of understanding sequence economies.

To understand these failures in credit markets, recall what Maynard Keynes (1936) pointed out in his *General Theory of Employment, Interest and Money*. Lenders have to deal with the "moral hazard" of the borrowers choosing not to repay, as discussed in Hammond (1989a). Of course, wise lenders try to ensure that borrowers always find this default option unattractive. But the world is full of prominent examples where lenders have failed to make the default option so unattractive that borrowers avoid it. In the case of lending to past repressive governments of the third world which have since been overthrown, this is surely a blessing. In the case of the failure to regulate adequately many of the Savings and Loan Institutions in the United States, it is a double curse. There is going to be a serious drain on the public exchequer. And it seems that too many who are guilty of fraud will escape unpunished to repeat their crimes.

To prevent all loan defaults is obviously impossible. To reduce them substantially would involve more careful and costly monitoring of debtors' and banks' balance sheets. It might even require revised accountancy standards. Creditors need to be able to assess more easily the exposure of any borrower to changes in market circumstances, and what future cash flows will be needed by what dates in order to honour debt contracts. This is just the kind of meticulous attention to detail that all but vanished when the regulations governing those fringe banks which are now causing so much trouble were relaxed a few years ago. This is why Hayek's scheme for allowing free competition in the supply of currency strikes me as complete lunacy. Credit markets require centralized coordination in a way which markets for physical commodities do not. Otherwise a smart borrower could mortgage the same house fifty times over. If the capital markets of the European Community are indeed to be integrated, this should be done with extreme care. Incentive compatibility teaches us that no loan is safer than the unwillingness of the borrower to exercise the default option. And so additional loans to the same borrower increase the riskiness of those made previously, even if the lender is different. The serious analysis of capital markets in sequence economies is only just starting.

10. Conclusions

I have kept my promise not to say how the world economic system should be organized, though it must have been clear that there are some changes which I might like to see. The role of information in the economy is a difficult topic which we are only just beginning to explore properly. Indeed, I fear that we are still at the stage of unlearning the old ideas which seemed to make sense when it was common to assume that everybody in the economy had access to the same information. Efficient allocation of resources without gross distributive injustice often

requires interference in markets beyond the simple lump-sum redistribution which was assumed by the old theory but which is now understood to be incentive incompatible. Market forces may constrain economic policy, and make things worse than they would be if markets could be suppressed or controlled. The risk of default by borrowers, however, may prevent some important markets from functioning at all. Interactions between different incentive constraints become complicated.

It is already clear that there has been an information revolution in economics, and that the subject can never be the same again. For economics, understanding the role of information in the economic system is analogous to, and perhaps even more important than, understanding the function of the blood stream has been for medicine. Nevertheless, too much economic policy still resembles bloodletting. Economists need to use their new understanding of information in order to seek improved treatments for such maladies as poverty, hunger, unemployment, depression, debt, inflation and pollution. A good start could be made by questioning all the old dogma concerning the role of markets when information is dispersed. The last few years have seen market forces having their praises sung in high political places the world over, some of them quite inconceivable just a few years ago. Market forces certainly deserve our respect no less than sailors should respect the tide. But wise sailors turn tides to their advantage, and will steer their boats or even put down their anchors rather than let themselves be swept away onto the rocks. Those rocks may be approaching much faster than some of our political leaders and their economic advisers have yet realized.

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