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Friedrich von Hayek and mechanism design

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Abstract I argue that Friedrich von Hayek anticipated some major results in the theory of mechanism design.

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1 Introduction

Mechanism design is the engineering part of economic theory. Usually, in economics, we take economic institutions as given and try to predict the economic or social outcomes that these institutions generate. But in mechanism design, we reverse the direction. We begin by identifying the outcomes that we *want*. Then, we try to figure out whether some mechanism – some institution – can be constructed to *deliver* those outcomes. If the answer is *yes*, we then explore the form that such a mechanism might take. Sometimes the solution is a "standard" or "natural" mechanism - - e.g. the "market mechanism." Sometimes it is novel or artificial. For example, the Vickrey-Clarke-Groves (Vickrey 1961; Clarke 1971; Groves 1973) mechanism can be used for obtaining an efficient allocation of public goods - - which will typically be underprovided in a standard market setting (see Samuelson 1954).

Friedrich von Hayek's work was an important precursor to the modern theory of mechanism design. Indeed, Leonid Hurwicz – the father of the subject – was directly inspired by the Planning Controversy between Hayek and Ludwig von Mises on the

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one hand and Oskar Lange and Abba Lerner on the other to develop the theory (see Arrow 2007).

In the Planning Controversy, Lange and Lerner asserted that central planning can in principle *replicate* the workings of the free market. Indeed by correcting market failures, central planning, they claimed, can even *improve* on market performance (see, for example, Lange 1942 and Lerner 1944). By contrast, Hayek and Mises denied that a centralized system – or, for that matter, any other non-market mechanism – could ever approach the success of the free market (see, for example, Mises 1933). Hayek gave at least two reasons why the free market cannot be improved upon. First, he asserted that other Pareto optimal mechanisms – mechanisms leading to Pareto optimal allocations of resources – require more *information* than the market does. That is, a consumer or producer has to *report* more information about himself (e.g., his preferences or technology), and he needs to *know* more about other consumers and producers (e.g., about their demands and supplies). Second, Hayek claimed other Pareto optimal mechanisms, unlike the market, are in conflict with consumers' and producers' own interests, i.e., they are not *incentive compatible*.

I will suggest in this paper that the mechanism design literature has provided precise treatments of these two claims. Specifically, it has established that Hayek's first assertion is, in fact, *correct* in settings in which there are no significant externalities (so that, in particular, there are no public goods). Moreover, the literature has also verified his second claim, given the additional assumption there are large numbers of consumers and producers (so that none of them has market power). Section 2 looks at the informational assertion, and Section 3 at the incentives claim. I offer a few additional remarks in Section 4. In keeping with Hayek's informality, I will express the main results nonmathematically (but will offer technical formulations in square-bracketed remarks).

2 Informational efficiency

Hayek (1945) argued that competitive markets are *informationally efficient*: "The most significant fact about this system is the economy of knowledge with which it operates, or how little the individual participants need to know in order to take the right action."

Mount and Reiter (1974) and Jordan (1982) formalized this idea. Here is a version of their approach that focuses on consumption and leaves out production. That is, we look at a *pure-exchange economy*, where the only economic activity is trade in goods that are in fixed supply. Each consumer cares only about how much he consumes of each good (so we are ruling out externalities). [Formally, there are n consumers and r goods and we will suppose each consumer i has a fixed endowment of goods, $w^i=(w_1^i \ldots w_r^i)$. Consumer i's preferences over consumption bundles w^i+x^i (where $x^i=(x_1^i,\ldots,x_r)$ is the vector of i's net trades) are represented by a utility function $u^i:\mathbb{R}_+^r\rightarrow\mathbb{R}$, where $u^i\in U$, and U is the set of all increasing, quasi-concave, and continuous functions on $\mathbb{R}_+^r$].

A *mechanism* specifies:

(i) a *message space* for each consumer, which consists of the set of messages he might "report" (either directly or through his actions) about his preferences over the goods [Formally, a message space for consumer i is an arbitrary set M^i];

(ii) a *message rule* for each consumer, which specifies the message that he actually reports, given his preferences and his information about other consumers' messages [Formally, a message rule for consumer i is a mapping $\mu^i{:}U\times Q^i\to M^i$, where Q^i is the set of possible signals that i might receive about other consumers' messages and $\mu^i(u^i,q^i)$ is the message that i reports, given his utility function u^i and his signal $q^i\in Q^i$];

and

(iii) an *outcome function*, which specifies the net trades that each consumer makes and the information he receives about other consumers, given all the messages reported [Formally, an outcome function is a mapping $\phi{:}M^1\times\ldots\times M^n\to\mathbb{R}^{rn}_+\times Q^1\times\ldots\times Q^n$, where $\phi(m^1,\ldots,m^n)=(x^1,\ldots,x^n,q^1,\ldots,q^n)$].

For example, let's consider the *market* mechanism. In that case a, consumer's *message* will consists of the net trades he proposes to make [Formally, consumer i's message space M^i is $\mathbb{R}^r$, and i's message m^i ($\in M^i$) is a vector, $x^i=\left(x^i_1,\ldots,x^i_r\right)$]. The *signal* that a consumer receives amounts to the market prices that prevail [formally, $Q^i=\mathbb{R}^r_+$ and $q^i=(p_1,\ldots,p_r)$], and his *message rule* prescribes the net trades that he most prefers, given his preferences and those prices [Formally, $\mu^i(u^i,p)=x^i$, where x^i solves

$$\max_{\hat{x}^i} u^i\left(w^i+\hat{x}^i\right) \text{ subject to} \sum_{j=1}^{r} p_j\hat{x}^i_j\leq 0\Big]. \tag{1}$$

Finally, the market mechanism *outcome function* generates the net trades that consumers propose [that is, the net trades are $(m^1,\ldots,m^n)=(x^1,\ldots,x^n)$] and gives rise to prices that bring total supply $\left[\sum_{i=1}^{n} w^i\right]$ and total demand $\left[\sum_{i=1}^{n}\left(w^i+x^i\right)\right]$ into alignment (i.e., the price of a good will be high if demand exceeds supply and low if supply exceeds demand) [Formally, given messages $(m^1,\ldots,m^n)=(x^1,\ldots,x^n)$, the outcome consists of the net-trade vector $(x^1,\ldots,x^n)$ and prices $p=(p_1,\ldots,p_r)$ such that p maximizes the value of excess demand, i.e., it solves $\max_{\widehat{p}} \sum_{i=1}^{n}\sum_{j=1}^{r}\widehat{p}_j x^i_j$[1]].

Next, we need to define the concepts of feasibility, Pareto optimality, and individual rationality. A mechanism is *feasibl*e, if, regardless of preferences, it results in a feasible outcome - - an outcome for which demand for any good does not exceed its supply [Formally, a feasible outcome consists of messages $(m^1,\ldots,m^n)$, net trades $(x^1,\ldots,x^n)$ and signals $(q^1,\ldots,q^n)$ such that

$$\begin{aligned}\left(m^1,\ldots,m^n\right) &= \left(\mu^1\left(u^1,q^1\right),\ldots,\mu^n(u^n,q^n)\right)\\ \left(x^1,\ldots,x^n,q^1,\ldots,q^n\right) &= \phi\left(m^1,\ldots,m^n\right)\end{aligned}$$

and

$$\sum_{i=1}^{n} x^i\leq 0.$$

[1] In this choice of prices, we are following Arrow and Debreu (1954), but this is not the only possible choice.

The mechanism is feasible if, for all utility functions $(u^1,\ldots,u^n)$, there exists a feasible outcome[2]].

A mechanism is *Pareto optimal* if it is feasible and every feasible outcome is Pareto optimal [Formally, if $(x^1,\ldots,x^n)$ are the net trades in a feasible outcome, then there exist positive weights $(\lambda^1,\ldots,\lambda^n)$ such that $(x^1,\ldots,x^n)$ solves

$$\left.\max_{\left(\widehat{x}^1,\ldots,\widehat{x}^n\right)} \sum_{i=1}^{n} \lambda^i u^i\left(w^i+\widehat{x}^i\right) \text{ such that } \sum_{i=1}^{n} \widehat{x}^i \leq 0\right].$$

Finally, a mechanism is *individually rational* if, in every feasible outcome, consumers are at least as well off as with their initial endowments [Formally, if $(x^1,\ldots,x^n)$ are the net trades in a feasible outcome of the mechanism, then $u^i(w^i+x^i)\geq u^i(w^i)$ for all i].

To formulate the Mount-Reiter and Jordan results, note first that the market mechanism requires that a consumer *report* only a single number for each good (his proposed net trade of that good). Thus, if there are r goods, the "dimension" of his message is r.[3] Similarly, to decide what message to send, a consumer has to *know* only a single number for each good (its price). And so, the dimensionality of his signal space is also r.[4] The first result says that any Pareto optimal mechanism requires consumers both to *report* as much and to *know* as much as they do in the market mechanism. [Formally, in any Pareto-optimal mechanism $\{M^i,\ \mu^i: U\times Q^i\rightarrow\mathbb{R}^r,\ \phi: M^1\times\ldots\times M^n\rightarrow \mathbb{R}^{rn}\times\mathbb{R}^r_+\}$, the dimension of M^i must be at least r–1 and the dimension of Q^i must be at least r–1]. Conversely, if a non-market mechanism is both Pareto optimal and individually rational, then each consumer must either report or know *strictly* more than in the market mechanism [Formally, for a Pareto-optimal and individually rational mechanism, $\dim M^i=\dim Q^i=r-1$ can hold only if the mechanism is the market mechanism].

3 Incentive compatibility

Hayek (1945) noted of the market mechanism that "nobody has as yet succeeded in designing an alternative system [in] … which the individual can choose his own pursuits and consequently freely use his own knowledge and skill." That is, no other mechanism is consistent with the individual's own objectives - - the market mechanism is uniquely incentive compatible.

A formal treatment of this claim is given in Hammond (1979). Hammond considers a *large* pure-exchange economy, i.e., an economy in which there are *many* consumers [formally, a continuum], all of whom are small relative to the economy. A mechanism is *incentive compatible* in a large economy if the message prescribed by a consumer's message rule is the message that best promotes his preferences [Formally,

[2] It is required that there *exist* a feasible outcome, not that *all* outcomes be feasible. Implicitly, the idea behind this weaker requirement is that, if the mechanism yields an infeasible outcome, signals and messages will adjust until feasibility is attained.

[3] Actually, it is only r-1, because from the equation $\sum p_j x^i_j=0$, we can deduce x^i_r from $x^i_1,\ldots,x^i_{r-1}$.

[4] Again, the actual dimension is only r-1 because prices can be normalized to sum to 1, and so, once we know $p_1,\ldots,p_{r-1}$ we can infer p_r from $\sum_{j=1}^{r} p_j = 1$.

$\mu^i(u^i, q^i(m^{-i})) = \arg\max_{m^i} u^i(\phi(m^i, m^{-i}))$, for all i, m^{-i} and u^i, where m^{-i} are the other consumers' messages and $q^i(m^{-i})$ is the signal that i receives about these other messages (the signal won't depend on *i's own* message if the economy is large)]. Hammond shows that in a large economy, a Pareto optimal and incentive compatible mechanism must give rise to the *same* net trades as the market mechanism. In other words, it must generate market outcomes.

4 Concluding remarks

Hayek did not go into great detail about how the market mechanism has to be modified if the hypotheses that the economy is large and that there are no externalities do not hold. In particular, he did not anticipate – as far as I can tell – the Vickrey-Clarke-Groves mechanism for determining a Pareto optimal public goods allocation.

Nevertheless, he was certainly aware that the market will not work well in the absence of those hypotheses. He was, for example, strongly in favor of ensuring that consumers and producers have no market power (so that the large-economy hypothesis holds). Specifically, he upheld an "argument against all exclusive, privileged monopolistic organizations" (Hayek 1960). For the case of public goods (where the no-externality hypothesis fails), he acknowledged that such goods cannot be provided by the market mechanism because they "cannot be confined to those who are willing to pay for them" (Hayek 1978).

On all this evidence, Hayek had a remarkable intuitive understanding of some major propositions in mechanism design – and the assumptions they rest on – long before their precise formulation. Indeed, his understanding seems to have been a guiding influence in their formulation.

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References

Arrow, K. (2007). Leonid Hurwicz: An appreciation. Unpublished.

Arrow, K., & Debreu, G. (1954). Existence of equilibrium for a competitive economy. *Econometrica, 22*, 265–290.

Clarke, E. (1971). Multipart pricing of public goods. *Public Choice, 11*, 17–33.

Groves, T. (1973). Incentives in teams. *Econometrica, 41*(4), 617–631.

Hammond, P. (1979). Straightforward individual incentive compatibility in large economies. *Review of Economic Studies, 46*(2), 263–282.

Hayek, F. (1945). The use of knowledge in society. *American Economic Review, 35*(4), 519–530.

Hayek, F. (1960). *The constitution of liberty*. London: Routledge & Kegan Paul.

Hayek, F. (1978). *New studies in philosophy, politics, economics, and the history of ideas*. London: Routledge & Kegan Paul.

Jordan, J. (1982). The competitive allocation process is informationally efficient uniquely. *Journal of Economic Theory, 28*(1), 1–18.

Lange, O. (1942). Economics of socialism. *Journal of Political Economy, 50*(2), 299–303.

Lerner, A. (1944). *The economic of control: Principles of welfare economics*. New York: Macmillan.

Mises, L. (1933). Planned economy and socialism. reprinted in Richard M. Ebeling ed. *Selected Writings of Ludwig von Mises*, The Liberty Fund, 2002.
Mount, K., & Reiter, S. (1974). The informational size of message spaces. *Journal of Economic Theory, 8*(2), 161–192.
Samuelson, P. (1954). The pure theory of public expenditure. *Rev Econ Stat, 36*(4), 387–389.
Vickrey, W. (1961). Counterspeculation, auctions, and competitive sealed tenders. *J Financ, 16*(1), 8–37.