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The Economics of Incentives: An Introductory Account

I am honored to have been asked to present the first Nancy L. Schwartz Memorial Lecture. This invitation was extended without any suggestion of how I might most fittingly pay tribute to Nancy's memory. The only orders were that I present a public lecture, rather than a research seminar. It would, for example, be reasonable for me to review Nancy's scholarly contribution and to place it in perspective. When you recall that her publications included more than forty articles and two books and when you keep in mind the range of the contribution, from the mathematics of optimization to the theory of market structure, you can see that I would have had my work cut out. Alternatively, I could have chosen to present an exposition of recent research on the theory of oligopoly; as you know, Nancy was an expert in this area. But instead of either of these topics, I have decided to speak on the economics of incentives, an area that was not at the center of Nancy's research interest.

Let me begin by explaining this choice. A professor contributes to his or her university in a variety of ways. Most important, he or she is a researcher and a teacher. At a great university such as Northwestern, these tasks are more closely related than one might think. For Nancy, the education of doctoral students was an integral part of her own research, and the excellent dissertation "Dynamic Games of Research and Development with Rivalry," written by Jennifer Reinganum, is but one of many examples supporting this claim. One can see in the dissertation the guiding hands of Mort Kamien and Nancy. In addition to his or her duties as a scholar and teacher, the senior professor sometimes serves as a manager and a recruiter. This work tends to be much less well rewarded than the production of outstanding research. From 1977 to 1979, Nancy chaired the Department of Managerial Economics and Decision Sciences, and from the time that she arrived at Northwestern in 1970 until her passing, she was a major force in shaping the MEDS department. During those years, the Kellogg School moved from "good" to "very good" to "distinguished" in the eyes of most graduate management school watchers. During the same period, the MEDS department moved from nowhere to the largest and very best department of its kind in the world – a department that Harvard, Yale, Stanford, and, I must add, my own university have repeatedly tried to raid, with but limited success, in order to stay abreast of the latest developments.

The MEDS department is by now a rather well-rounded group with broad strengths; however, it is no secret that substantial credit for the reputation it has achieved must go to the remarkable advances that have been made here in the economics of incentives.

*The Economics of Incentives**

From its infancy in the eighteenth century, the framework of economic analysis has had three major ingredients. First, it takes as axiomatic that economic agents act on their own behalf, with or without sympathy for others. It does not judge self-interested action to be immoral or unworthy of serious study. Quite the contrary, it suggests that the pursuit of one's own interest describes well economic behavior and asks us to develop its consequences. Second, the framework takes *social* equilibrium to be the concern of economic analysis. Economics is a branch of *social* science, and as such it requires at least two potent actors. The laws of physics and chemistry exist in the absence of mankind. For psychology it may be enough that there is a single human being. However, for sociology, political science, and economics, you need at least

*This text formed the basis for public lectures that I presented at several universities during the years 1981-83. It was originally published in *Technology, Organization and Economic Structure*, eds. Ryuzo Sato and Martin J. Beckmann, no. 210 in *Lecture Notes in Economics and Mathematical Systems*. New York: Springer-Verlag, 1983.

two people. Finally, the framework of economic analysis takes the goals of individual economic agents to be in conflict; it views it as the business of economics and social science to determine the extent to which this conflict does or does not result in the efficient use of resources, promote the social good, and so on.

The really big contributions to economics all fall within the framework I have outlined: economics is the study of social equilibrium that results from the acquisitive behavior of several agents with conflicting goals. Adam Smith taught us to consider carefully the possibility that selfish acquisitive behavior might in some way promote the social good. Marx praised the early achievements of capitalism, but he believed that the ownership of capital and its direction by a relatively small number of profit-seeking capitalists would lead to increasingly severe depressions and eventually to the collapse of capitalism itself. Smith and Marx shared a common framework, but they emphasized different issues and thus were led to different conclusions. Walras proposed a detailed mathematical theory of what it means for an agent to act on his or her own behalf, and he used this theory to explain the relative value of goods and services. Pareto helped us to understand the meaning of a socially efficient use of resources; and modern welfare economics, in particular as embodied in the work of Kenneth Arrow, provides a rigorous treatment of the relationship between the outcome of self-interested behavior, as formalized by Walras, and social efficiency, as defined by Pareto.

And to be sure, this framework does not leave out macroeconomics. The classical "big question" of macroeconomics concerns the possibility that the acquisitive behavior of individual agents may lead to unemployment or to recurrent booms and busts. Marx looked for answers to these questions in a new political and social order. Keynes looked for answers to these questions in the possibility of a role for government in the regulation of aggregate economic variables.

So, with this common framework, why is it that economists appear to disagree so very much when faced with the most basic questions? I am not speaking of disagreement that stems from differences of fact (for a while, people in macro liked to hide behind this as a basic reason for disagreement); rather, I am speaking of disagreement that implies a complete divergence of opinion on how economic processes work or can be made to work. Two engineers may disagree on whether or not a rocket will go up because of questions regarding the values of certain hard-to-measure parameters. But their difference is not a result of the fact that they subscribe to different physical theories. It is my contention that economists so often come down on both sides of the same question because they don't have a theory that is adequate to handle the issues at the heart of the question. Furthermore, I believe that, more often than not, the piece of theory that is missing would be provided in a more complete economics of incentives.

Let me be concrete by defining one of the paradigmatic problems in the economics of incentives.

> Question: Is it possible that private acquisitive behavior will lead to the construction of a socially optimal amount of sidewalks and streetlights? Or, with such joint consumption goods, that is, public goods, will selfish behavior necessarily lead to misrepresentation and inefficiency? With public goods, is it *necessary* to have a benevolent planner, or an occasionally elected planner, who guesses the preferences of the populace and coerces agents into paying for the cost of new projects?

Not only is this problem at the heart of the economics of incentives, but you surely realize that it falls squarely in the center of the framework for economic analysis that I put forth at the beginning of the essay: acquisitive behavior, social equilibrium, conflicting goals.

Let me be a bit more precise. I am not asking whether the economists' stylized model of perfect competition, as put forth in any principle course, will lead to the construction of an optimal sidewalk and streetlight system. Of course it will not. As *a part of the definition of selfish acquisitive*

behavior, I allow agents to write contracts and set up governments that enforce those contracts. Just as I can sign a paper that promises that I will deliver two tons of red winter-wheat in St. Paul this August 10, I can choose to participate in a society in which a vote of the majority can force me either to move or to pay for a portion of the cost of a sidewalk and streetlight project. In short, my notion of acquisitiveness includes the possibility that I choose strategically where to live, and that I might bind myself to quite involved contracts.

When I went to graduate school, there were two accepted answers to the sidewalk and streetlight problem. The reason that there were two answers is that there were two accepted ways of looking at the problem – much as if creationism and evolutionary theory had equal status. And the reason that there were two accepted ways of looking at the problem is that there was not yet an economics of incentives. Sadly, but predictably, the answers yielded opposite conclusions.

The first answer we were taught was based on a paper by Samuelson [6]. For simplicity, assume that sidewalks and streetlights are produced at constant marginal cost; each additional unit costs the same amount. An optimal sidewalk and streetlight system (for a mid-size city) might be roughly proportional in size to the number of inhabitants. For example, it might involve an expenditure of $100 per person. For a sidewalk and streetlight system to be optimal, it is necessary for the sum of the marginal benefits to consumers, for another $100 of expenditure, to be equal to $100. One can finance the optimal sidewalk and streetlight system by charging each consumer the private marginal benefit he receives from the last $100 unit of sidewalk and streetlight times the number of $100 units provided. As the number of residents goes up, the number of units of sidewalks and streetlights goes up, and the marginal benefit of an additional $100 of sidewalks and streetlights to each resident goes down. In the example, each agent is asked to pay the same amount ($100) no matter what the size of society, but the marginal benefit to him from his expenditure goes to zero as he is imbedded in a larger and larger society.

Samuelson said that in such a case an acquisitive consumer would "free ride." Given the free choice to contribute his "fair share" (his marginal benefit times the number of units provided) to the financing of sidewalks and streetlights, he would selfishly maximize his welfare by claiming that his marginal benefit is zero. Then, his "fair share" would be zero times the number of units provided, which is zero, and he would lose only the marginal benefit of the $100 of extra sidewalks and streetlights that his contribution would provide – essentially nothing. He could in fact use the $100 he saves to buy private consumption goods, for example, chocolates, or whatever. We are left with the clear impression that a society composed of a collection of acquisitive agents will not be able to solve the problem of providing public goods in the amount that would be socially desirable.

Samuelson referred to this inadequacy as the "free-rider problem." He identified an incentive problem and said that it had no solution. The implicit policy prescription is that we must rely on the actions of a benevolent planner, who guesses (perhaps scientifically) the preferences of agents and implements socially desirable plans.

The second answer with which we were provided was based on a classic paper by Ronald Coase [2]. To be fair, it is Coase taken to an extreme, and I do not believe that it would have gone over so well on a qualifying examination. This answer comes to the opposite conclusion from the one suggested by Samuelson: one argues that the sidewalk-streetlight problem is no problem at all! For if the project proposed initially, including its financing, is not optimal, then a collection of citizens can propose an alternative plan, which will benefit some and hurt none. Clearly it will be unanimously favored. Agents, pursuing their own self-interests, will commit themselves to such a plan voluntarily. Thus, selfish behavior will lead to the optimal provision of sidewalks and streetlights. You will of course recognize that the above argument ignores the strategic aspects of group decision making. I may oppose a plan that would lead to an improvement in my

welfare if I believe that the next plan on the agenda would benefit me even more. Nevertheless, the argument continues to be sold.

During the past 20 years we have made great strides in our understanding of the sidewalk and streetlight problem. We recognize Samuelson's answer as being particularly unimaginative regarding the possibility of cooperative behavior, and similarly we recognize the Coase answer as trivializing the problem of cooperation. Economic research now almost routinely takes up the problem of whether or not there are institutions that will enforce cooperative behavior, institutions that will get the sidewalks and streetlights built in precisely the amount that is socially optimal. We now consider the possibility of "designing cooperation," just as engineers have been concerned with the problem of designing electric switches. We are very much at the stage of basic research, more physics than real engineering, but I want to argue that our success has been real, and I want to emphasize that this achievement has been at the very top of what has happened in economics during the last couple of decades.

To my mind there is no hope that economists will speak "with one tongue" until we understand the economics of incentives and the possibility of designing cooperative behavior. In order to understand unemployment you must understand the labor contract. In order to understand the labor contract you must understand the economics of incentives. When workers and managers get together, they have the opportunity to sign contracts that contain cost-of-living and severance pay clauses. The fact that they are capable of designing quite imaginative contracts has a *profound* effect on macroeconomics.

The purpose of this essay is to illustrate, by the use of simple examples, some of what we have learned. The material is quite striking, and if you are being exposed to it for the first time, then I believe you are in for a treat. The first illustration is very, very simple.

Five siblings are to inherit some land from their father, who is their surviving parent.

The father is concerned that the land go to the sibling who places the highest dollar value on it. To make matters simple, assume that the siblings are at this point independently wealthy and that the father plans to leave all of his other possessions to charity. Also assume that, once inherited, the land cannot be sold. The father decides to hold a sealed-bid auction. He sits the siblings down, far away from each other, in his large drawing room, and he tells them that the sibling who bids the most gets the land for the price that he or she bids. Think of yourself as a participant in this auction. Certainly you will bid no more than you believe the land is worth to you. In fact, you would be likely to try to figure out how much your siblings might bid and to use this information in shading your own bid. You might even consider the fact that your siblings may be taking into account the fact that you are taking into account what they might bid. The result is that you have an incentive not to tell the truth. Think of what this means for the example at hand: the person who gets the land may not be the one who values it the most. And this outcome is not socially efficient, for there is then a trade that will benefit both the person who values it most and the person who got it!

This conclusion has much the same feel as Samuelson's articulation of the free-rider problem. Individuals act strategically; they don't tell the truth, and the joint outcome might be quite bad. Can this be overcome, can we design a solution?

Vickery [8] explained a resolution to this problem. The patriarch of the family should announce that the land will go to the highest bidder at the *second* highest bid. Now imagine yourself again as one of the children. I claim that you can do no better than to bid the true value that you place on the land, and of course in this case the child who gets the land is the one who values it the most. Consider two cases: (a) you tell the truth and get the land, and (b) you tell the truth and don't get the land.

In either case, even if you know exactly how your siblings bid, could you do better? Let us consider (a). You could shade your bid, but this doesn't affect what you pay. By misrepresenting your preference all you

could do is lose the land, which by telling the truth you get at a price below what it is worth to you. Thus you can do no better than tell the truth. You should figure out case (b) yourself.

We have designed a situation in which in the language of game theory, truth is a dominant strategy. You can do no better than tell the truth. How about that! In this scheme it is in the interest of each agent to tell the truth, and the person who gets the land is the one who values it the most. By choosing a clever scheme we assure a socially efficient outcome. Now let's get a bit more sophisticated.

We return to the case of a public project. The project costs \$1000 and there are ten agents. As a baseline proposal consider the plan that the project will be built and each agent taxed \$100. Define the net benefit v_i accruing to the i^{th} agent to be the maximum amount that the agent would be willing to pay to have the project built and receive a \$100 assessment, rather than not to have the project built. Note that the net benefit to the i^{th} agent may be positive, negative, or zero. If people would tell the truth, then a sensible scheme for deciding whether or not to build the project is first to sum the v_i's. Then, if the sum is nonnegative, the project should be built; and if the sum is negative, it shouldn't be built. With this as a basis, one might ask people to declare the net value of the project to them (let w_i be the declared value for agent i), and build the project if $\Sigma w_i \geqq 0$. But there is an obvious problem. If $v_i > 0$, then i wants the project built and he might as well declare w_i equals 3 billion dollars. Similarly, if $v_i < 0$, then i does not want the project built and he might as well declare −5 billion dollars. Clearly, it is not necessarily in each agent's interest to tell the truth.

Enter Groves and Clark, [4] and [1]. These economists independently designed a scheme that makes truth a dominant strategy and gets the project built precisely when the sum of the net benefits is nonnegative. Here is how their scheme works. As before, let w_i denote the net benefit declared by i. The project is built if and only if $\Sigma w_i \geqq 0$. In addition, if the project is built i pays \$100 and receives a sidepayment of

$\sum_{j \neq i} w_j$. If the project is not built, i pays nothing and receives no sidepayment.

Just as with the land auction, one shows that for each agent truth is a dominant strategy ($w_i = v_i$), by considering the following two cases: (a) i tells the truth and $\Sigma w_j \geqq 0$, and (b) i tells the truth and $\Sigma w_j < 0$. Consider first (a). Since $\Sigma w_j \geqq 0$, the project is built. The net benefit to i before he receives a sidepayment is v_i; after the sidepayment his net benefit is $v_i + \sum_{j \neq i} w_j$. Since we assume i tells the truth, $v_i = w_i$ and so $v_i + \sum_{j \neq i} w_j = \Sigma w_j \geqq 0$. Thus i's net benefit is nonnegative if he tells the truth and the project is built. By declaring a net benefit other than v_i, the i^{th} agent can only change his payoff ($v_i + \sum_{j \neq i} w_j$) if he chooses w_i so low that the project is not built. But then his net benefit would be zero. Thus truth is the best strategy no matter what valuations w_j ($j \neq i$) are declared by the other agents. Again, (b) is left to the reader.

This is indeed a remarkable result; it is simple but penetrating. After seeing it, one does not so lightly say that it is not possible to design cooperation. It looks as if Samuelson was just not quite clever enough. The free-rider problem is not essential. People can read the work of Groves and Clark and bind themselves to schemes that promote the social good. The perspective is that self-interested agents will bind themselves in this way.

But it turns out that there are some delicate problems that arise if you try to apply schemes of this type generally. To give a hint, note that the government in the Groves-Clark runs a big deficit. We could correct this by adding a negative constant to the sidepayments and hope for balance on average, but this does not solve all of the problems. A more serious defect is that we must assume that the preferences of all individuals are of a special form (called the transferable utility form) in order to justify the rule that a project be built when the sum of the net benefits is positive.

In fact, there is no way to solve all of the incentive problems, and this is the conclusion of a remarkable result known as the Gibbard-Satterthwaite theorem, [3] and [7]. This is a negative result, but it must be

listed among the really important contributions to social science in the last couple of decades, for it helps us to understand the limits of what is possible. Like all truly fundamental results, it is easy to explain if not to understand the details of how it is established.

Consider a set of alternatives

$$A = \{x^1, x^2, \ldots, x^m\};$$

these might be candidates for office, or alternative government budgets. We will assume that $m \geqq 3$ and that there are n agents. A *social choice function* is a rule that assigns to each n-vector of rankings of A, a social choice $x \in A$. For the case of three alternatives (x,y,z) and four people, a typical point in the domain of a social choice function is

1	2	3	4
x	x	y	z
y	z	z	x
z	y	x	y

This might have associated with it the alternative x, with the interpretation that when the four agents vote as indicated, the outcome is x. For simplicity we will assume that for each alternative there is some ranking that will make that alternative the social choice.

A social choice function is *strategy-proof* if no agent can ever secure a more favored outcome by misrepresenting his preference. A social choice function is *dictatorial* if there is some agent who always gets his first choice, no matter how the other agents vote.

The Gibbard-Satterthwaite theorem tells us that any social choice function that is strategy-proof is dictatorial. In other words, the only general scheme that aggregates preferences to make social choices and is strategy-proof is the dictatorial scheme. Needless to say, the dictatorial scheme does not involve serious mediation. This argues strongly for the Samuelson side of the Samuelson-Coase difference to which we have been alluding; however, one can hardly credit Samuelson with the Gibbard-Satterthwaite insight.

The Gibbard-Satterthwaite theorem is sort of a Pandora's box. Once the result is known, there is no taking it back, and knowledgeable agents will not believe that it is in their interest to tell the truth without trying to discover the rule by which preferences are to be aggregated or how other agents are voting. This can lead to intuitively unattractive consequences, and I like to illustrate this point by recalling, in a wildly embellished form, my experience at the University of Massachusetts.

I taught at UM for three years. Department chairmen were elected for three-year terms, but for several consecutive years each chairman resigned or was dismissed at the end of nine months. The members of the department became very sophisticated at voting. In my last year there were four candidates: first, the darling of the macroeconomists in the the department, John M. Keynes. We had it on good authority that JM was most anxious to come to UM because of the exciting cosmopolitan environment. The second candidate was named F. Y. Edgeworth. He was in fact my own choice, and rumor had it that he was fascinated with the architecture of our campus. Nothing against Keynes, but FY was really well plugged into the microeconomics establishment, and I felt certain that he would be a most valuable critic and appreciator of my work. Two candidates remained, John Glutz and Stu Smith. Glutz was the candidate of the provost and Smith was the candidate of the acting dean. None of us had ever heard of either of them. There was some gossip that Glutz possessed information about an indiscreet act committed by the provost during his younger days as an assistant professor at a university to our south. Blackmail was the name of the game! Later we learned that Smith was the acting dean's real name (we knew him only as dean). The acting dean had nominated himself with the hope that he could become a "real" chairman after he was finished "acting."

There were eleven macroeconomists in the department and eleven microeconomists. The former were all for JM, and the latter all favored FY. Of course, both

groups favored FY and JM over the remaining candidates; they were indifferent between the nominations provided by the acting dean and provost. The voting was by rank order. List the candidates: the first choice on a ballot gets four points, the second gets three, etc. The total number of points obtained by each candidate is added, and the candidate with the largest number of points wins.

I picked up my ballot and immediately voted: FY, SS, JG, and JM. The reasoning was clear: I knew that either FY or JM would win, and I wanted to get the most distance between them. Well, it turned out that everyone was as sophisticated as I was: everyone put FY and JM first or last. SS was second on two thirds of the ballots, and this is how the acting dean became chairman of the economics department at UM. This was so intolerable that there were mass resignations.

The next day I kicked myself for being so devious. But if we had been allowed to revote, I might have done the same again. If I thought that my colleagues had "learned their lesson" and were going to vote their true preference, then it would have been in my interest to remain devious! In any case the point should be clear. If a scheme is not strategy-proof, then it may be in an agent's interest to misrepresent his preference, and this can lead to outcomes that are quite undesirable in terms of the voters' own preferences. There is no benevolent invisible hand at work here!

Let us now return to the "good news." Faced with the difficulty of the Gibbard-Satterthwaite theorem, we ask, is there hope of designing cooperation in a general context? One direction that has been explored is to weaken the notion of social equilibrium. At the same time, it is necessary to introduce schemes that have agents choose actions from sets other than the set of all possible preferences over social outcomes. Consider for a moment the case of two agents. The first picks from the set $\{a_1, a_2, \ldots, a_n\}$ and the second picks from the set $\{b_1, b_2, \ldots, b_m\}$. A game form is an

$n \times m$ matrix, where for each i and j the ij entry is the outcome if the first agent plays a_i and the second agent plays b_j. In the Groves-Clark scheme, each agent has a "best play," and it is independent of the play chosen by other players. This is the case of equilibrium in dominant strategies. Now we will require less for social equilibrium, namely, that the strategies chosen are "Nash."

The Nash equilibrium concept essentially does the following. It associates to each game form and each set of individual preferences (these define the utility payoffs of the game) a play for each agent. The assigned plays have the property that, given the plays attributed to others, no agent can improve his position by altering his own play. If you believe that all of the other agents in a game in which you are participating have read and believe the work of Nash, and if everyone has the information to determine the game in which he is playing, then the best you can do is make the play assigned by Nash. The weakness of the Nash equilibrium concept is that it requires each agent to know the preferences of all other agents. This is not true with dominant strategy equilibrium.

Great strides have been made in constructing game forms for economies with public goods so that each Nash equilibrium is associated with a good outcome. The first and perhaps the most significant of these was due to John Ledyard and Ted Groves [5]. By loosening the notion of equilibrium from dominant strategy to Nash, they were able to get around the difficulties presented by the Gibbard-Satterthwaite theorem. But a resolution via Nash equilibrium, because of its strong informational requirement, is not entirely satisfactory. It may still be in an agent's interest to misrepresent his preferences to others.

To understand this point, consider two games, I and II. The payoffs in the ij^{th} place are the utilities for A (who chooses a_1 or a_2)

and B (who chooses b_1 or b_2), respectively, when the joint choice is (a_i, b_j).

I

		B: b_1	B: b_2
A	a_1	1,1	3,4
	a_2	2,5	1,6

II

		B: b_1	B: b_2
A	a_1	1,4	3,1
	a_2	2,6	1,5

Suppose that I give the true utility payoffs and both agents know the utility numbers. A can see that if he plays a_1, then B would do best to play b_2 (since $4 > 1$). Similarly, if he plays a_2, then B would do best to play b_2 (since $6 > 5$). Thus, A can be sure that B will play the dominant strategy b_2, and on this basis A does best to play a_1. The pair (a_1, b_2) is in fact the unique Nash equilibrium for I.

But suppose that B can convince A that his utility payoffs are as indicated in II. Then, reasoning as before, A can be sure that B will play the dominant strategy b_1, and on this basis A does best to play a_2, which makes (a_2, b_1) the unique Nash equilibrium for II. But in terms of B's true preferences you will see that this outcome yields B the payoff 5, while in I, where A knew B's true preference, B only received the payoff 4. The point is clear: with Nash equilibrium it may be in an agent's interest to misrepresent his preferences in order to secure a better outcome. Furthermore, as indicated in the "voting for a chairman" example, such misrepresentation can be expected sometimes to lead to socially inferior outcomes.

But I do not want you to draw the conclusion that schemes based on Nash equilibrium are useless and teach us nothing. Rather, I would say that there are at least two features that must be taken into account in the design of mechanisms for promoting cooperative behavior. First, the informational requirements: who has to know what? Second, the incentive problems: is it in each agent's self-interest to act as we have prescribed for him to act? This classification follows the work of Leo Hurwicz, who pioneered the abstract approach to the design of schemes.

Schemes based on Nash equilibrium may sometimes have rather strenuous informational requirements (e.g., everyone's true preference is common knowledge), but we should still appreciate what they are able to do for the incentive problem: agents acting in their own behalf, but with possibly the need for substantial amounts of information, will selfishly promote the social good. Furthermore, one can always hope that by improving the design we can lessen the informational requirements. This is the direction of current research.

I will close this essay by reviewing the major points.

1. The economics of incentives is at the core of economic theory. It applies not only to public goods allocation, but also to such questions as: how can a firm owner get a manager to perform in the owner's interest? What directions should society give to the managers of a public utility?

2. It is possible to be much more inventive in the design of schemes than was foreseen by Samuelson. You now know some schemes. But this is not to say that I foresee so much progress in the design of schemes that such ideas will replace the need for governments to indirectly estimate costs and benefits, and to proceed to construct projects that yield the largest net benefit.

3. There are limits to how far one can go with schemes that make it in each agent's interest always to tell the truth; the Gibbard-Satterthwaite helps us to precisely understand these limits.

4. Nash equilibrium provides a way around these limits, but at the cost of large informational requirements. One can substantially solve the incentives problems if each agent has a great deal of information about the agents he is participating with.

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