

The Invisible Hand — Invisible Because It Does Not Exist?*

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Abstract

We argue that the application of game theory to economics leads to a serious challenge to the supposed benevolence of Adam Smith’s Invisible Hand. The usual view in economics is that the Invisible Hand works, i.e., individualistic behavior leads to the largest economic pie, unless market imperfections or failures are present. Starting from a game-theoretic approach, all interdependencies are *a priori* present in an economic system, and to be sure that the Invisible Hand will work, one must be sure that various interdependencies are absent. This analytical reversal — from a question of presence to a question of absence — reverses the burden of proof. The presumption is now that the Invisible Hand does not work, unless it can be shown that interdependencies are limited in the appropriate way. We explain that, while game theory has long been applied to economics, this key insight has been obscured by the fact that it has been applied in a piecemeal rather than holistic fashion. We end with a brief reference to the biological view that members of our species have prosocial as well as self-interested tendencies — and to some additional issues this raises for an analysis of the Invisible Hand.

1 Game Theory vs. The Invisible Hand

There is a well-known scene in the movie *A Beautiful Mind*¹ in which the young game theorist John Nash and his fellow male Princeton students are watching some women who have just entered the Princeton bar. Should they all compete for the attentions of the “most attractive” one? Nash’s fellow students appear to think so. Indeed, proud of their erudition, they invoke Adam Smith’s Invisible Hand to claim that it is even to the common good that they do so. Looking up suddenly from his pile of books, Nash strongly disagrees:²

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“Adam Smith said the best outcome for the group comes from everyone trying to do what's best for himself. Incorrect. The best outcome results from everyone trying to do what's best for himself **and the group.”**

Nash lays out an alternative — and, to his mind, superior — strategy for him and his colleagues to follow to gain the attentions of the women.

This is, of course, a fictional account, so it provides no information about what the real John Nash might say about the Invisible Hand. But is the fictional Nash correct? Does game theory really tell us, in some general and profound way, that if everyone follows the prescription of doing the best for oneself, the result may well not be the best group or social outcome? If so, this would be a striking proposition. A belief that the Invisible Hand works much of the time underlies the presumption in favor of unfettered markets that is prevalent in economics today.

In this essay, we will argue that in an interdependent world, game theory should seriously undermine confidence in the benevolence of the Invisible Hand.

2 Game Theory and the Pie

If game theory really undermines the Invisible Hand, why is this fact not widely known?³ After all, game theory is a widely used mathematical tool — used extensively in modern economics, in particular. We will argue that while there is indeed a lot of game theory in economics nowadays, the way game theory has been used serves to obscure this fundamental issue.





	Do not confess	Confess
Do not confess	1 Year 	0 Years 
Confess	20 Years 	5 Years 

Figure 1

We start with the most famous game model of all, the Prisoner's Dilemma.⁴ See Figure 1. The story is well known. There is sufficient evidence to convict both suspects, Alice and Bob, of a minor crime (1-year sentence each), but insufficient evidence to convict the suspects of a more serious crime (5-year sentence each) unless at least one of them confesses. The police offer a carrot (no time served) and a stick (20-year sentence) in such a way that each suspect is better off confessing, regardless of what the other suspect decides to do. In this game, when each player makes the best individual choice (“Confess”⁵), they fail to arrive at the best joint outcome for them (which would be a 1-year sentence each).

All this is clear and is well known. What is not so clear is whether the outcome in which Alice and Bob both confess is good or bad under some appropriate measure of the overall worth of the game — what can be called the overall “pie.” Perhaps, society is best off if Alice and Bob are each kept out of circulation for 5 years. Perhaps not, because they have families which depend on them. The point is that the Prisoner’s Dilemma model does not provide enough information for us to decide. What is missing is a definition of the overall pie — and a way of saying how the players’ actions in a game affect this pie. We need a game theory that talks about these concepts.

Turning to economics, if we want to use game theory to understand whether or not the Invisible Hand works, we need to be able to pose within game theory the question:

When players follow their individual interests, do the choices they make lead to the largest overall economic pie?

We need a game theory that includes a definition of the overall economic pie and that also contains a principle that explains how players’ actions affect the size of this pie.

3 A Patchwork of Models

This is not the game theory that has, for the very large part, been used in economics. To see this, start where economics starts, which is with the so-called perfect market as depicted by the usual supply-and-demand diagram. The largest possible pie is the area between the supply and demand curves. This is precisely the pie that will result if the market price is the one that goes through the intersection of the two curves, and sellers and buyers transact at this price. In the language of economics, the outcome is efficient.⁶

The next step is to analyze markets which depart from this one, because of the presence of “imperfections” such as market power (monopoly, oligopoly, etc.), externalities (also termed “market failures”), or other features. This is the point at which game theory enters the picture. But, the way game theory enters is via a patchwork of models. For each feature, there is a large repertoire of purpose-built game models used to examine it. For example, for oligopoly, there is the Cournot model, the Bertrand model, and many others. Textbooks often contain literally dozens of different such models.⁷

For each specific model, we can analyze how that model works and answer the question of whether or not the outcome is economically efficient. But, this case-by-case approach does not allow us to answer the question: What are the general conditions under which economic efficiency does or does not result? An answer that says efficiency results in this model, but not in that model, and so on, is not very illuminating.

What is needed is a general game model of the pie and of how the players’ actions affect the size of the pie.

This model needs to be capable of describing a wide variety of markets. With such a model, we can hope to identify general factors that determine whether or not the Invisible Hand works.

4 Preview

There is such a game model. It can be built by going back to the early days of game theory and looking at how John von Neumann (in his seminal 1928 *Mathematische Annalen* paper⁸) and then von Neumann together with Oskar Morgenstern (in their 1944 book *Theory of Games and Economic Behavior*⁹) began to develop a theory of how “value” (i.e., the pie) is created by and divided among the players in a game.

We will apply this general model (more precisely, a development of it) to the question of when is it true that players, following their individual interests, make choices that lead to the largest overall pie. Our answer is a complete reversal of the usual one. The usual answer is that the Invisible Hand works, unless various kinds of market imperfections or failures are present. This is the natural answer when one starts with the perfect market and works outwards from it, so to speak. But, when we start with the general game model, there is a striking reversal. Our answer goes:

For the Invisible Hand to work, various kinds of interdependencies among market participants have to be ruled out.

The default is now that the Invisible Hand will not work — unless conditions happen to be appropriate to it.

Default bias, which means too easily accepting a default or status-quo option, is a well-studied human cognitive error.¹⁰ This means that it matters a great deal which default view of markets is accepted. With the first view — the orthodox view — the conclusion will be that, very often, markets work well. With the second view — the view that comes from our general game model — this conclusion will be much less likely to be reached. Confidence in the benevolence of the Invisible Hand will be much reduced.

Our finding would certainly justify the label¹¹ of economics as the “dismal science,” and it is our main challenge, as game theorists, to economic orthodoxy. Under conditions of individualistic behavior, there is no presumption that the largest pie will be created. This said, we will end this essay by drawing on the biological view that members of our species have prosocial as well as self-interested tendencies. Our prosocial side may help us work with others to create the largest pie, when self-interested behavior does not suffice. Still, we shall see that there does not appear to be an obvious bottom line for economic efficiency.

5 Back to von Neumann

In 1928, John von Neumann wrote a seminal paper in game theory that formulated and proved the famous Minimax Theorem for two-person zero-sum games.¹² Less well known is that in this same paper he began the study of general n -person games. Von Neumann’s idea was to build a game model of interactions among several players, not by describing detailed moves and countermoves, but instead by describing the possibilities for “creating value” open to all the different subsets of players. For example, consider a subset consisting of Alice (a seller) and Bob (a buyer), and suppose Alice has a cost of \$15 of making her product while Bob has a willingness-to-pay for her product (the maximum price he would pay, while still seeing benefit in the purchase) of \$25. The value or “pie” created by this subset is then $\$25 - \$15 = \$10$. Similar calculations give the value created by all other subsets of players in a game. Figure 2 illustrates the idea.

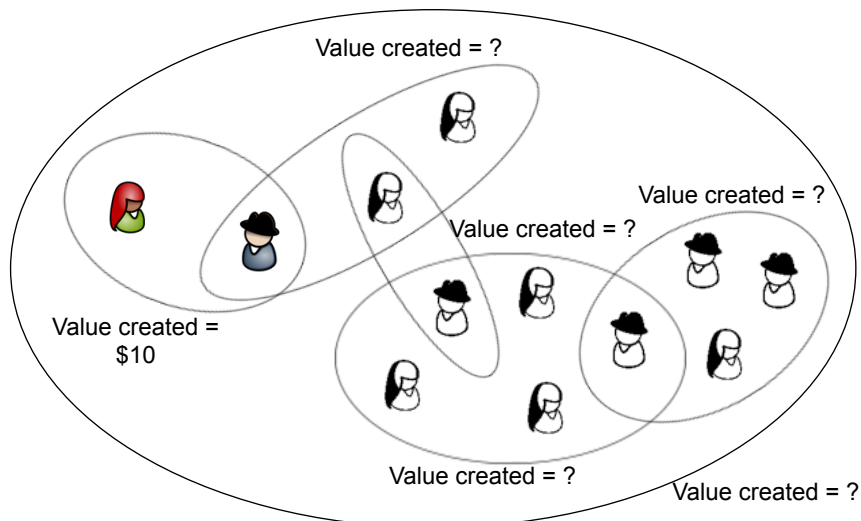
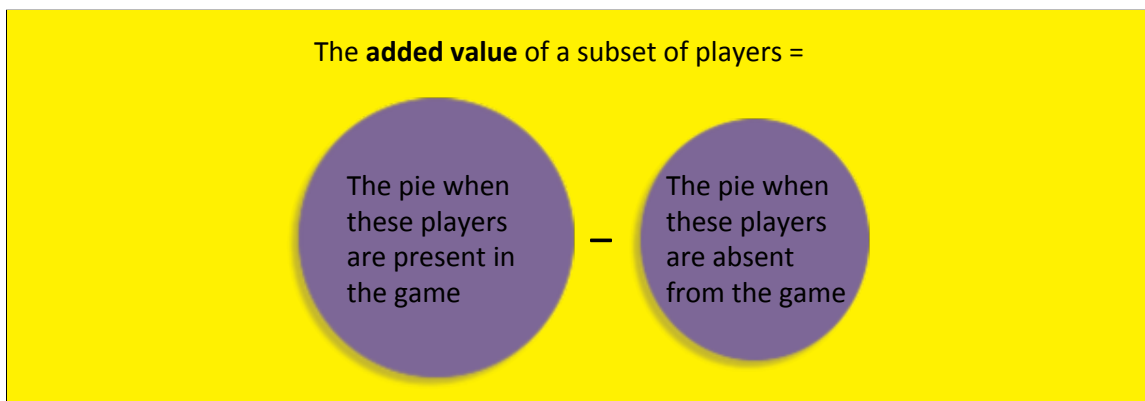


Figure 2

In the 1944 book *Theory of Games and Economic Behavior*,¹³ von Neumann, now working with Oskar Morgenstern, began the full-fledged study of markets using this idea. From here and subsequent work in game theory in the 1950s, a general theory of markets emerged. A key concept in this theory is:¹⁴



A fundamental tool, called the Core of a game, circumscribes the division of the total value of a game among the players. It relies on the principle that no subset of players receives more value than the added value of that subset.¹⁵ Mathematically speaking, this amounts to a set of linear inequalities. Conceptually speaking, it captures the idea that the participants in a market seek out the best deals they can. As a result, no group of players will be able to take more from the game than that group brings — i.e., than that group's added value.¹⁶

Example 1 In addition to Alice and Bob as earlier, there is now a second potential buyer, Charlie, who, like Bob, has a willingness-to-pay of \$25 for Alice's product. However, Alice only has sufficient product to sell to Bob or to Charlie, not to both. Thus, the total value created in the game is again

$\$25 - \$15 = \$10$ (not twice this). Alice's added value is $\$10 - \$0 = \$10$, since no value is created without her presence. Bob's added value is $\$10 - \$10 = \$0$, since Alice can always sell to Charlie; by symmetry, Charlie's added value is also $\$0$.

Since the Core implies, in particular, that no individual player can get more than that player's added value, we see that Bob and Charlie capture no value in this game, while Alice captures the entire pie of $\$10$. Of course, this makes intuitive sense, since Alice is in a monopoly position in supplying the product,¹⁷ and Bob and Charlie compete for the limited supply.

While this example of using the model is very simple, the model itself is very general and we can use it to conduct a general — rather than case-by-case — analysis of economic efficiency vs. inefficiency.¹⁸

6 Good Incentives

The Invisible Hand concerns the effects of individual action, so let's look at the incentives facing each individual player in a game. The concept of added value gives a big clue as to what we might hope for. Suppose each player anticipates being rewarded with what that player brings to the game — i.e., with that player's added value. Then, we might hope that individual interests will be properly aligned with the collective interest, and the largest possible pie will result. Here is a condition on a game under which players will indeed be rewarded this way:

A game exhibits **No Bargaining Problems** if the sum, over all the players, of each player's added value is equal to the total value of the game:

$$\sum_{\text{All players } i} \text{Added value of player } i = \text{The total value of the game.}$$

We give the proof that under this condition, each player will receive exactly his added value in the game. No player can receive strictly more than his added value (i.e., more than he brings to the game), so the only alternative case we have to consider is that some player receives strictly less than his added value. But then, since the added values sum to the total value of the game, at least one other player would have to receive strictly more than her added value. However, we have already noted that this is impossible. The conclusion is that each player will receive exactly his added value, and no less.¹⁹

The next example shows that, without the condition of No Bargaining Problems, there is no reason to hope that individual interests and the collective interest will be aligned. (It will also make clear why the condition is so named.) In fact, it will turn out that even with this condition, we do not yet have enough for the Invisible Hand to work. In the following two sections, we will need to delve more deeply into the interdependencies in a game.

Example 2 Alice and Bob each has to decide, separately, whether or not to pay $\$3$ to a third party.²⁰ If they both pay $\$3$, they are in a position to transact with each other and together create $\$10$ of value. See Figure 3.

The efficient choice is for Alice and Bob each to pay the $\$3$, since the resulting net pie of $\$10 - \$3 - \$3 = \4 is positive. But it is not clear that the players will necessarily find it in their individual

interests to do so. This will depend on how each expects the negotiation over splitting the \$10 to go. If Alice anticipates receiving less than \$3 out of the \$10, then we can guess she will decide not to pay the \$3 upfront; and similarly for Bob.

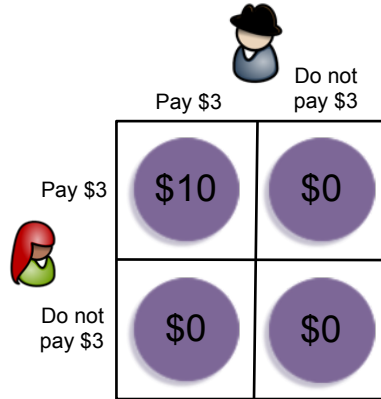


Figure 3

This example can be viewed as a highly stylized model of the relationship between two businesses, Alice Inc. and Bob Inc. Each business has to build an office near the headquarters of the other business, if they are to be able to transact with each other. If both businesses make this upfront investment, then they can transact and make a joint profit to be divided among them.²¹

Let's calculate the added values, at the point when Alice and Bob have both already made their upfront investments. There is a (gross) value of \$10 to be created at this point. Each player has an added value of $\$10 - \$0 = \$10$. Clearly, it is impossible for both players to receive their full added values, since the sum of their added values exceeds the pie — it is actually equal to twice the pie. If, before making their upfront investments, Alice and Bob both anticipate receiving at least 3/10 of their added values, then we can guess that the efficient choices (invest) will be made. But, Alice might think that Bob will end up with almost all of his added value, or Bob might think this about Alice, in which case we can guess that the efficient choices will not be made.

The example illustrates the fact that bargaining problems among players may prevent individual choices from leading to an economically efficient outcome.²² The condition of No Bargaining Problems rules out this obstacle because, under it, there is nothing to bargain over. The workings of competition alone dictate that each player will receive his full added value.

When might this condition hold? A very important special case is the perfect market with which we began. Figure 4 gives the idea. There is a very large number of sellers (strictly, infinitely many) each with a different cost (arranged in the upward-sloping supply curve) and a very large number of buyers (infinitely many) each with a different willingness-to-pay (arranged in the downward-sloping demand curve). Sellers and buyers each transact very small (infinitesimal) quantities, which is why the curves are smooth.

The added value of a seller is a shaded rectangle (of infinitesimal width) extending from the seller's point on the supply curve to the intersection of the supply and demand curves. This is because, without this seller in the game, the just-excluded seller (located as shown in the diagram) would now be able to transact. By the symmetric argument, the added value of a buyer is a shaded rectangle (of infinitesimal width) extending from the buyer's point on the demand curve to the intersection of the supply and demand curves. Now, the key observation: If we sum up all the players' added values, we get exactly the area between the two curves — i.e., we get exactly the

total pie. The condition of No Bargaining Problems is satisfied. This implies that the players — sellers and buyers — will receive exactly their added values.

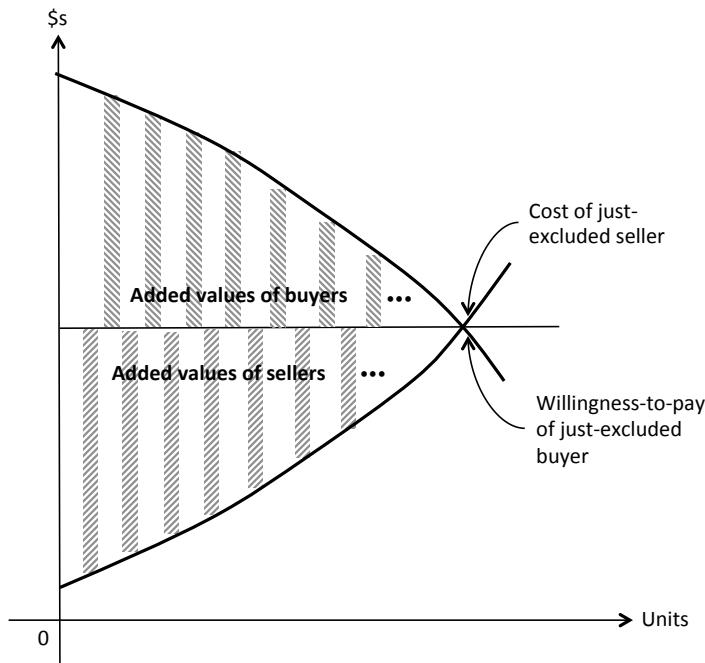


Figure 4

This is a very important instance of when the No Bargaining Problems condition is satisfied, for a reason we will explain in a moment. First, though, let's note that it is certainly not the only instance. A particularly simple one is Example 1 from earlier. The sum of the added values is $\$10 + \$0 + \$0 = \10 , which is the total value. Example 3 below is another instance. Other examples could readily be constructed. The case in Figure 4 is very important because it shows how the general game-theoretic model we are using reduces to the conventional perfect-market model in the limiting case. To see this, ask how much value a seller would receive under conventional supply-and-demand (rather than game-theoretic) analysis of Figure 4. The answer is the market-clearing price (which is the y -coordinate of the horizontal line that goes through the intersection of the supply and demand curves) minus that seller's cost, times an infinitesimal quantity. For a buyer, it is that buyer's willingness-to-pay minus the market-clearing price, again times an infinitesimal quantity. These are the same quantities as the players' added values we just calculated, and we just saw that these are what the players receive under the game-theoretic analysis.²³

This is a very important test of a new theory — that it reproduces the old theory under the appropriate limiting conditions. (The most famous examples of this phenomenon are, of course, the reductions of relativistic and quantum mechanics to classical mechanics in the relevant limits.) In the game-theoretic model of markets we are using in this essay, the relevant limit is when there are very large numbers of sellers and buyers, each of whom is very small. The theory passes this limit test.

Once one recognizes that the perfect market is a limiting case, the question arises: A limit of what? By definition of a limit, there must be a limiting sequence. But what is this sequence? That there was a missing sequence — a missing theory of markets with finite numbers of participants

— was the brilliant insight that von Neumann and Morgenstern had in the introductory chapter in *Theory of Games and Economic Behavior*:²⁴

“The theory of mechanics for 2, 3, 4, ... bodies is well known, and in its general theoretical (as distinguished from its special and computational) form is the foundation of the statistical theory for great numbers. For the social exchange economy --- i.e., for the equivalent ‘games of strategy’ --- the theory of 2, 3, 4, ... participants was heretofore lacking”

When we practice game theory à la von Neumann and Morgenstern, we turn the order of economic analysis on its head. We start with small numbers of participants — what are conventionally called imperfect markets — and get to the perfect market in the limit. This reversal comes as a consequence of the goal von Neumann and Morgenstern set themselves of developing a general theory of markets. It is this theory, further developed, which we are using in this essay and which leads to a second reversal — the reversal of the burden of proof concerning the Invisible Hand. Let’s now return to this argument.

7 Externalities are Not Exceptionalities²⁵

The condition of No Bargaining Problems is our first attempt at formulating the circumstances under which the Invisible Hand works. It sounds promising. If each player is rewarded with his added value, then he will be led to try to increase his added value. Because an increase in the total value will lead to an increase in each player’s added value, it is tempting to conclude that each player will act in such a way as to increase the total value. If so, individual choices on the part of the players will lead to the creation of the largest pie. The Invisible Hand will work.

But, there is an invalid step in this argument. The reason is that there are two ways for a player to increase his added value. One is to increase the total size of the pie with him. The other is to decrease the total size of the pie without him. This second route causes a problem for the Invisible Hand.

Example 3 *Alice, Bob, and Charlie each hold a black playing card, while Dan and Eve each hold a red playing card. See Figure 5. We think of this as a simple market in which any two cards together, provided one is black and one is red, are worth \$100. Alice, Bob, and Charlie can each try to sell a black card to Dan or Eve. Or, Dan and Eve can each try to sell a red card to Alice or Bob or Charlie. (The players on each side of the market are required to negotiate individually; they cannot form coalitions.)*

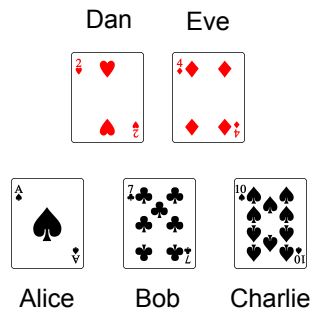


Figure 5

The total pie is \$200 (the constraint is the number of red cards). Alice, Bob, and Charlie all have added values of \$0, while Dan and Eve each have an added value of \$100. The No Bargaining Problems condition holds, so the players will get exactly their added values. Now, suppose that, before the negotiations begin, Alice manages to dog-ear the black cards that Bob and Charlie get. Assume that a red card and a dog-eared black card are together worth \$50 (rather than \$100). The total pie is now \$150. Bob and Charlie still have added values of \$0. If Alice was not in the game, then there would be only the two dog-eared black cards left, so the pie would shrink to $50 + 50 = \$100$. Therefore, Alice's added value is now $150 - 100 = \$50$, a positive number. If Dan was not in the game, the pie would shrink to \$100.²⁶ So, Dan and Eve each now have an added value of $150 - 100 = \$50$. The No Bargaining Problems condition again holds, and so, in particular, Alice will get her added value of \$50. Evidently, it is to Alice's benefit to dog-ear the black cards that Bob and Charlie get.

The key to Alice's strategy is the effect it has on the size of the pie without her. The pie with her shrinks from \$200 to \$150, but the pie without her shrinks by more — from \$200 to \$100. The result is that her added value goes from zero to a positive number. We have arrived at the game-theoretic definition of the economic notion of an externality:

A game exhibits **No Externality Problems** if, taking each player i at a time (and holding constant the pre-negotiation choices made by all the players other than i), the choices i makes do not affect the pie created by all the players other than i .

When Alice dog-ears the other two black cards, she imposes an externality — a negative externality²⁷ — on the other players. The strategy is effective for her, but it is economically inefficient since it leads to a smaller total pie than is possible. If we want to rescue the Invisible Hand, we need to impose the condition of No Externality Problems. The point, once again, is the analytical reversal. Under our game-theoretic view of an economic system, interdependence is the base case and, therefore, externalities are the base case. It is not the case for questioning the Invisible Hand that has to be made, but the reverse case.²⁸

8 A Failure to Coordinate

There is still one more interdependence in an economic system, as we have modeled it, that has to be ruled out to ensure that the Invisible Hand will work. Even if the conditions of No Bargaining Problems and No Externality Problems are met, there can be a situation where individual players fail to coordinate their choices — with the result that a smaller-than-possible pie is created.

Example 4 There are three players Alice, Bob, and Charlie. Their choices are depicted in Figure 6, where Alice chooses between the two rows (“No” or “Yes”), Bob chooses between the two columns (“No” or “Yes”), and Charlie chooses between the two matrices (“No” or “Yes”).²⁹ For each of the 8 triplets of choices by the three players, the corresponding cell in the two matrices gives the value created by each subset of players. In each cell, the three-box icon refers to the subset consisting of all three players, the first two-box icon refers to the subset consisting of Alice and Bob, the second two-box icon refers to the subset consisting of Bob and Charlie, and the third two-box icon refers to the subset consisting of Alice and Charlie.

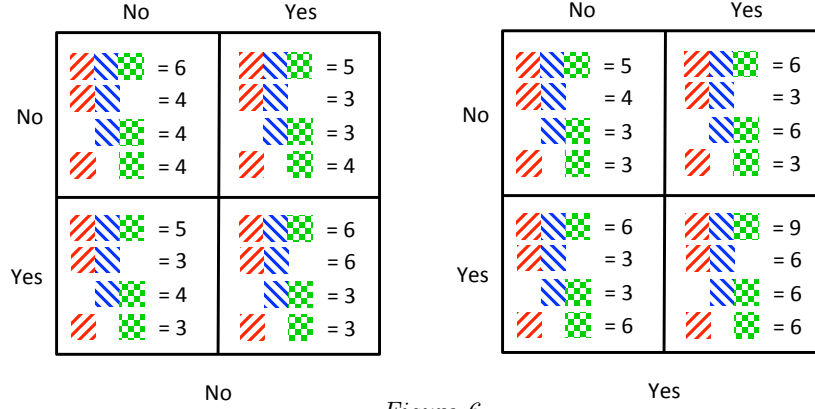


Figure 6

The example can be thought of as a stylized situation of choosing standards, like the much-studied cases of technological standards.³⁰ The choice “No” means staying with an existing standard, while the choice “Yes” meaning adopting a new standard. If all three players adopt the new standard, the total pie (the entry 9 in the lower-right cell of the right-hand matrix) is larger than the total pie (the entry 6 in the upper-left cell of the left-hand matrix) if all three players stay with the existing standard. The new standard is superior to the existing one.

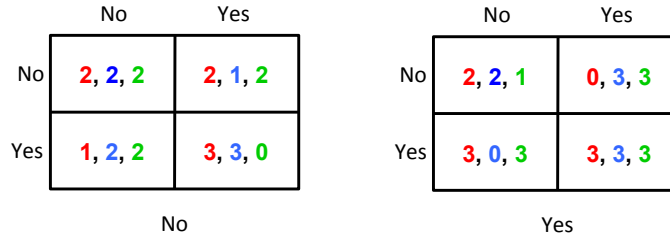


Figure 7

Figure 7 gives the players’ added values (in the order Alice, Bob, Charlie in each cell), calculated from Figure 6. The numbers in Figure 6 are carefully chosen so that both the condition of No Bargaining Problems and the condition of No Externality Problems are satisfied. By the first condition, Figure 7 gives not just the added values but the actual payoffs to the players. The key observation is that while the choices (Yes, Yes, Yes) yield the largest total pie (equal to 9), there is no reason to think that these choices will necessarily be made. In particular, the choices (No, No, No) have the stability property of being a Nash equilibrium,³¹ but yield a total pie of only 6.

In the example, each player receives exactly his added value, and is unable to affect the size of the pie without him. So, here (unlike in Example 3), each player has an incentive to act in such a way as to maximize the overall pie. Yet, the Invisible Hand still does not work. The reason is that to arrive at the largest the pie, the players need to coordinate their choices. At the choices (No, No, No), each player’s choice maximizes the pie, subject to holding the other two players’ choices constant. We can see from Figure 7 that if one player happens to switch from No to Yes, then the other two players will be led to switch, too, and the largest pie will result. But, no player has an incentive to initiate the switch. Here is a condition that rules this situation out:

A game exhibits **No Coordination Problems** if the maximum of the overall pie can be found by maximizing the overall pie player-by-player.

Once more, we see the analytical reversal. The base case is interdependence and, therefore, coordination issues are the base case, too. They must be explicitly ruled out for the Invisible Hand to work.

9 An Invisible Hand Theorem

The three restrictions on interdependence in a game which we have identified are together sufficient for the Invisible Hand to function:³²

If a game exhibits **No Bargaining Problems, No Externality Problems, and No Coordination Problems**, then each player has a dominant strategy and, when these strategies are played, the largest overall pie is created.

By a “dominant” strategy for a player is meant a strategy that is optimal for that player, regardless of the strategies chosen by the other players. The Prisoner’s Dilemma (Figure 1) is the most famous example of a game with dominant strategies (“Confess”). The Invisible Hand Theorem identifies conditions on a game under which there are again dominant strategies, but, this time, to be sure that the play of these strategies leads to the largest overall pie.

Under a game-theoretic view of an economic system, the starting point is full interdependence, i.e., the assumption that “everything depends on everything else.”³³ Under this view of the world, there is nothing odd or atypical about interdependencies in the form of bargaining, externality, or coordination issues. The conditions of No Bargaining Problems, and No Externality Problems, and No Coordination Problems become special cases, and no longer the base cases. There can no longer be a presumption in favor of the Invisible Hand.

10 Postscript on Prosocial Behavior

Could there be a happier conclusion? An important assumption underneath the Invisible Hand Theorem is that economic ‘actors’ behave in a purely self-interested fashion. Suppose, instead, we allow that members of various groups choose actions for the joint benefit of their respective group, even when these actions conflict with self-interest. We could even go to the opposite extreme and suppose that all actions are chosen to maximize the joint benefit to everyone, i.e., to maximize the overall pie. Economic efficiency would then be guaranteed.

The prosocial instincts of humans work in this direction, and so we should be grateful for our prosocial side. However, absent the special conditions of the Invisible Hand Theorem, this effect will be countered by our self-interested tendencies. It is tempting to try to produce a bottom line: By virtue of our prosocial side, we succeed in creating the largest pie together. Or, by virtue of our self-interested side, many opportunities to increase the overall pie are missed. The primatologist Frans de Waal warns against trying to produce a simple conclusion.³⁴

“[W]e are group animals: highly cooperative, sensitive to injustice, sometimes warmongering, but mostly peace loving. A society that ignores these tendencies can't be optimal. True, we are also incentive-driven animals, focused on status, territory, and food security, so that any society that ignores those tendencies can't be optimal, either. There is both a social and a selfish side to our species.”

There is another reason to be cautious about drawing a simple conclusion. The theory of multi-level selection proposes that it is group-versus-group competition that leads to prosocial adaptations within groups.³⁵ Unless the group is humanity as a whole (which seems extremely far-fetched), then the problem of the self-interested individual now re-appears at the level of the self-interested group.³⁶ Bargaining across groups, externalities across groups, and coordination issues across groups will become new obstacles to the creation of the largest pie at the ‘global’ level across groups. Perhaps, our prosocial side makes an interdependent economic system less dismal a place than it would be if people were purely self-interested. But we do not claim to see a bottom line. What does seem clear is that the Invisible Hand, if not a completely invisible idea, is certainly a very elusive one.

Notes

¹Universal Studios, 2001.

²*A Beautiful Mind: The Shooting Script*, by Akiva Goldsman, Newmarket Press, 2002, p.24. Bold in quote added.

³Some readers have said that we are setting up a straw man here, and this fact is widely known among ‘sophisticated’ economists. Perhaps, but a glance at leading microeconomics textbooks (a good example is Mankiw, N.G., *Principles of Microeconomics*, 6th edition, South-Western, 2011) shows that thousands of economics students every year are told that markets mostly work well when left to their own devices — with the implications this has for the worlds of public discussion of economics and policy making in economics.

⁴Created in 1950 at the RAND Corporation by Merrill Flood and Melvin Dresher. See Frank, R., *The Darwin Economy: Liberty, Competition, and the Common Good*, Princeton University Press, 2012, for important instances of the Prisoner’s Dilemma in real economic settings.

⁵Important implicit assumptions for this to be the best choice are: (i) the suspects are concerned only with the length of the sentences and with no other considerations (such as acquiring a reputation for ratting on one’s friends), and (ii) that the game is played only once. (“Do not confess” can be the best strategy in the Repeated Prisoner’s Dilemma; see Brandenburger, A., “The Power of Paradox: Some Recent Developments in Interactive Epistemology,” *International Journal of Game Theory*, 35, 2007, 465-492.)

⁶Efficiency is to be distinguished from equity, i.e., the issue of whether the division of the pie among the market participants is equitable. Advocates of free-market economics do not argue that an equitable division of the pie necessarily results.

⁷A good example is Tirole, J., *The Theory of Industrial Organization*, MIT Press, 1988.

⁸Von Neumann, J., “Zur Theorie der Gesellschaftsspiele,” *Mathematische Annalen*, 100, 1928, 295-320. (Bargman, S., English translation: “On the Theory of Games of Strategy,” in Tucker, A., and R.D. Luce (eds.), *Contributions to the Theory of Games, Volume IV*, Princeton University Press, 1955. 13-42.)

⁹Von Neumann, J., and O. Morgenstern, *Theory of Games and Economic Behavior*, Princeton University Press, 1944.

¹⁰See Samuelson, W., and R. Zeckhauser, “Status Quo Bias in Decision Making,” *Journal of Risk and Uncertainty*, 1, 1988, 7-59; “Overcoming Status Quo Bias in the Human Brain,” by Fleming, S., C. Thomas, and R. Dolan, *Proceedings of the National Academy of Sciences*, 107, 2010, 6005-6009.

¹¹Due to the 19th-century historian Thomas Carlyle.

¹²Von Neumann op. cit..

¹³Von Neumann and Morgenstern op. cit..

¹⁴The standard terminology in cooperative game theory is “marginal contribution.” The more user-friendly term “added value” was coined in Brandenburger, A., and H. Stuart, “Value-Based Business Strategy,” *Journal of Economics & Business Strategy*, 5, 1996, 5-24.

¹⁵The Core is presaged in Edgeworth, F., *Mathematical Psychics*, Kegan Paul, 1881; and von Neumann and Morgenstern op. cit.. It was formally defined in Gillies, D., “Solutions to General Non-Zero-Sum Games,” in Tucker, A., and R. D. Luce (eds.), *Contributions to the Theory of Games: IV*, Princeton University Press, 1959, 47-85.

¹⁶Geoffrey Miller asked us to emphasize that this argument presumes that all exchanges in an economy are voluntary, and neglects the role of coercive power — a neglect pointed out by various critiques of mainstream economics. We maintain this assumption of voluntarism, since it is implicit in the proposition that the Invisible Hand (mostly) works, and we want to give this proposition its best chance of holding up.

¹⁷The game-theoretic definition of a monopolist is a player who has an added value equal to the total value of the game.

¹⁸Advocates of using this model include L. Shapley and M. Shubik (“On Market Games,” *Journal of Economic Theory*, 1, 1969, 9-25; “The Assignment Game, I: The Core,” *International Journal of Game Theory*, 1, 1971, 111-130) and L. Telser (“The Usefulness of Core Theory,” *Journal of Economic Perspectives*, 8, 1994, 151-164). There is a misconception in many accounts of the history of game theory that von Neumann and Morgenstern did not have a full theory of n -person general-sum games. (See, e.g., Myerson, R., “Nash Equilibrium and the History of Economic Theory,” *Journal of Economic Literature*, 37, 1999, 1067-1082.) This is false. Fully one half of their book is devoted to laying out the foundations of the model of markets we are using. For a history of game theory that treats the early work carefully, see Leonard, R., *Von Neumann, Morgenstern, and the Creation of Game Theory: From Chess to Social Science, 1900-1960*, Cambridge University Press, 2012.

¹⁹In a fundamental paper (“Appropriation and Efficiency: A Revision of the First Theorem of Welfare Economics,” *American Economic Review*, 85, 1995, 808-827), Louis Makowski and Joe Ostroy introduced what we call the No Bargaining Problems condition into modern economics and demonstrated its role in yielding economic efficiency. There were 19th-century precursors — J.B. Clark and P. Wicksteed, in particular.

²⁰This and the following two examples use the biform games framework developed in Brandenburger, A., and H. Stuart, “Biform Games,” *Management Science*, 53, 2007, 537-549.

²¹In economics, this is called the “holdup problem.” We can imagine a number of possible solutions. For example, the businesses might write an upfront contract on how to divide the subsequent proceeds of \$10. Our point is not that the problem cannot be solved, but that there is a problem in the first place.

²²This phenomenon has been studied from a different direction under the name “transaction cost economics.” See Williamson, O., *The Mechanisms of Governance*, Oxford University Press, 1996.

²³The formal mathematical treatment of this argument is in the seminal papers Shubik, M., “Edgeworth Market Games,” in Luce, R.D., and A. Tucker (eds.), *Contributions to the Theory of Games: IV*, Princeton University Press, 1959, 267-278; and Debreu, G., and H. Scarf, “A Limit Theorem on the Core of an Economy,” *International Economic Review*, 4, 1963, 235-246.

²⁴von Neumann and Morgenstern op. cit., pp.14-15.

²⁵Our thanks to Corey Blay for suggesting this phrase.

²⁶Here, we assume that it is Alice and neither Bob nor Charlie who makes a deal with Eve, since, with her whole black card, Alice can always offer Eve a better deal than either Bob or Charlie can.

²⁷Whether an externality is classified as negative or positive depends on what the baseline is taken to be. If the baseline is that Alice does dog-ear the cards, then the move to dog-eared them creates a negative externality. If the baseline is that Alice does not dog-ear the cards, then the move to dog-ear them creates a positive externality.

²⁸Interestingly, the field of development economics has, for a long time, put externalities much more center-stage than has the usual market economics. Interdependencies — specifically, externalities — across industries are fundamental in the big-push theory of development. See Rosenstein-Rodan, P., “Problems of Industrialization of Eastern and South-Eastern Europe,” *Economic Journal*, 53, 1943, 202-211. For a mathematical model, see Murphy, K., A. Shleifer, and R. Vishny, “Industrialization and the Big Push,” *Journal of Political Economy*, 97, 1989, 1003-1026.

²⁹This is just a way of depicting the $2 \times 2 \times 2$ game matrix on a page. The example is from Brandenburger and Stuart op. cit..

³⁰A good resource on this topic is Arun Sundararajan’s webpage <http://oz.stern.nyu.edu/io/network.html>.

³¹Nash, J., “Non-Cooperative Games,” *Annals of Mathematics*, 54, 1951, 286-295.

³²Brandenburger and Stuart op. cit..

³³An ancient saying of the Haida people of the Pacific Northwest (see http://en.wikipedia.org/wiki/Haida_people): “Gina waadluxan gud’ad Kwaagiidang.”

³⁴De Waal, F., *The Age of Empathy: Nature’s Lessons for a Kinder Society*, Harmony Books, 2009, pp.4-5.

³⁵Wilson, D.S., and E.O. Wilson, “Rethinking the Theoretical Foundation of Sociobiology,” *Quarterly Review of Biology*, 82, 2007, 327-348.

³⁶Our thanks to Geoffrey Miller for making this excellent point.