

Working Paper

Dividing the Indivisible

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An office, or a mistress, cannot be apportioned out like a common. Jeremy Collier

Equity and indivisibility

Almost everything can be divided in one way or another. So when we say that something is indivisible, we usually mean that it is difficult or costly to divide, not that it cannot be divided. Indivisibles in this sense are commonplace. Children are indivisible. So are houses, paintings, and jobs. Spouses are for the most part indivisible, except in California. Indivisibles are often the focus of disputes in the family, especially in inheritance and divorce cases. They are also bones of contention in the international sphere. Prominent examples are territories that are considered indivisible for historical and cultural reasons, such as Berlin, Vienna, or Jerusalem. But things may be indivisible for a variety of other reasons: technological (broadcasting bandwidths), geometrical (the South Pole), symbolic (the name Macedonia), or aesthetic (the Mona Lisa).

Why are indivisibles so often a source of conflict? I want to advance the proposition that it is because they frustrate the parties' desire for justice. Since indivisibles are by definition difficult to distribute, it is hard to find a solution that treats all parties even-handedly. And when people think they have been treated unjustly they tend to get mad -- mad enough even to go to war. This is why indivisibles are so difficult to deal with, and why they have an important bearing on global security.

The broader issue with which we need to concern ourselves, then, is justice. When I say "justice" I do not mean the law, though the law is no doubt just -- at times. I mean something broader. I mean distributions that are *appropriate* and *fitting* given the various claims of the parties. Justice in this sense is hard to pin down -- especially when the parties have different *kinds* of claims. Yet we usually recognize justice (or the lack of it) when we see it. This intuitive sense of justice is what the romans called *equity* or "natural law." It stands in contrast to and in a sense above the law, which is often too rigid to accommodate the complexities and nuances of natural justice.¹

¹ In Britain, for example, equity was traditionally embodied in the Lord Chancellor, who was empowered to redress unduly harsh or inequitable legal judgments. This arrangement eventually evolved into a system of equity judgments and equity courts that were parallel to but distinct from courts of law.

Justice, in this broader sense, relies not only on institutions to enforce compliance, but also on the pressure of public opinion. No number of police and judges can substitute for the raised eyebrow to help bring deviants into line. But for this system to work there must be widespread agreement on what the appropriate norms of justice are. Moreover, people must be willing to exert social pressure when they have been violated. It stands to reason, then, that when shared values and enforcement mechanisms are weak, justice will be difficult to secure and the risk of conflict is heightened. Unhappily, this is exactly the situation in the international sphere.

Our task, then, is to examine situations in which several countries lay claim to the same indivisible thing, and to ask how they can negotiate a just and equitable settlement as an alternative to going to war. I should advertise at the outset, however, that the reader who expects to find in these pages a general *recipe* for distributive justice is going to be sadly disappointed. Philosophers notwithstanding, our intuitions about justice are far too subtle and varied to be captured in a single formula. My program is more modest. I propose to examine several concrete cases in which indivisibles played a role and in which apparently satisfactory solutions were found. Some of these cases are international, others lie closer to home. By studying their common features, I believe we can make some headway in thinking about how to allocate indivisibles in a more efficient and more equitable way.

Two international examples

Consider Jerusalem. Surely it is one of the greatest stumbling blocks to peace in the Middle East. Here, clustered within a few hundred yards of each other, are the holiest sites of three major religions. Here is the accretion of millennia of civilization, almost unbelievable in its complexity and diversity, yet also forming an organic whole. Nevertheless it is divisible. We could, for example, build a wall down the middle and top it with barbed wire, somewhat on the model of Berlin. Yet this would be close to sacrilege. It would be like sacrificing a living thing.

Or consider the atmosphere. The air is both a global commons and a global dumping ground. Each year billions of tons of carbon dioxide spew forth from factories, cars, campfires, and felled forests around the globe. Atmospheric scientists believe that the

accumulation of these pollutants will, sooner or later, have a major impact on global climate. The only real dispute is when it will occur and who will be hit hardest.

The atmosphere is divisible of course. One way to divide it, for example, would be to adopt a "greenhouse solution" to the "greenhouse problem." Countries could encase themselves in huge plastic bubbles, within which they could enjoy their own private climates controlled by their own private thermostats. This is preposterous of course. Quite aside from the expense, it would change the climate in drastic ways, altering currents, rainfall patterns, and temperature. In other words, it would destroy the essential properties of the thing being divided.

This brings us to a simple but important point. When we say that a thing is indivisible, like Jerusalem or the atmosphere, we do not literally mean that it cannot be divided. We mean that the object loses much of its *value* when divided. The key to the solution is to divide the object notionally rather than physically, by creating various kinds of rights to its use. In the case of Jerusalem, for instance, we could conceive of creating a quasi-autonomous city-state governed by a council of representatives from the various religious and ethnic groups. Control of municipal services would be delegated to local neighborhood authorities, and freedom of access would be guaranteed to all the holy sites.² This arrangement solves the problem of fair division by assigning powers, rights, and responsibilities in a creative way, not by dividing the object itself. This is how many large multi-ethnic cities are run anyway, and to some extent it is the way Jerusalem operates now.

Similarly, one can share the atmosphere by creating property rights to its use. One approach is to divide the cost that pollutants impose on others. This is an application of the common law principle that a person is entitled to money compensation for a nuisance caused by someone else. In practice it means charging an emissions tax. The tax can be set (at least in theory) so that the right amount of pollutants are emitted and people are fairly compensated for damages done.

While fair in principle, however, this is not a very practical solution. The tax rates would have to be quite high to have any bite, and the amounts of money collected could be quite enormous -- perhaps on the order of several hundred billion dollars per year. It is difficult

² For detailed plans along these lines see Albin (1991) and Rothman (1991).

to imagine setting up an international agency to collect this amount of money. It is even more difficult to see how they would dispense it, for in principle the funds should be used to compensate the injured parties, yet in practice it is almost impossible to estimate who has been injured and by how much (Young and Wolf, 1992).

A more sensible solution is for countries to agree voluntarily to meet certain emissions *quotas*. Property rights take the form of emissions permits, which may or may not be traded after the initial allocation. This approach has been adopted in a variety of recent cases. Under the revised Clean Air Act in the United States, electric power stations are allocated sulfur dioxide emissions permits in proportion to a base-period emissions rate (not to exceed a certain maximum amount), and they may trade their permits within defined geographical areas. Similarly, under the Montreal Accord on Substances that Deplete the Ozone Layer (1987), developed countries agreed to decrease their CFC emissions by a fixed percentage of their base-year emissions (with an eventual target of zero emissions), while developing countries were allowed to adjust on a more flexible schedule. In this case the permits are *not* tradable. It is significant, however, that in both cases the permits were allocated proportionally to the claimants' starting positions

How to cut a cake

These examples illustrate how indivisibles can be made divisible by creating new kinds of property rights. To appreciate the full range of solutions, however, it is helpful to step back for a moment and to ask how we allocate indivisibles that are closer to home. We are quite accustomed to dealing with them in the community and in the family. Who gets the children when the marriage breaks up? Who inherits the summer house and who gets the diamond? Who is first in line to receive a kidney for transplantation? Who is admitted to nursery school (or a nursing home)? In whose backyard is the hazardous waste dump located? Who gets to *decide* where the waste dump is sited? Society has devised ingenious ways to deal with these problems, and their solutions offer important clues about how to approach global ones.

Consider the problem of how to cut a cake (Steinhaus, 1948). Cake is divisible but not perfectly so: inevitably one part will not look the same as the other. (Perhaps one piece has more icing and the other has a cherry.) Yet even my children know how to solve this: one of them divides the cake into two pieces and the other gets first choice. This method has the merit that, although the pieces may be unequal, the divider can arrange things so

that the resulting allocation is *fair* in the sense that neither prefers the other's piece to his own.

I am certainly not suggesting that the divider need be a saint. Knowing that his little sister loves cherries, for example, the older brother will not doubt cut the cake so that the *smaller* piece contains the cherry. It's only sensible. The point is, however, that even with such manipulations the process works. A reasonably careful divider can cut the cake so that each prefers what he has to what the other has. In the economics literature such a division is said to be *envy-free* (Foley, 1967; Baumol, 1988; Thomson, 1990). I shall call this rough form of equality the *parity principle*.

Divide and choose is not merely child's play; it has also been successfully applied in the international arena. Consider the Law of the Sea negotiations, which were conducted under United Nations auspices in the 1970s (Sebenius, 1984). One of the most troublesome issues was how to divide mining rights to the ocean floor, which is strewn with nodules rich in nickel, cobalt, manganese, and other valuable minerals. Both then and now only a few industrialized countries have access to the capital and technical know-how to mine these nodules profitably. The developing countries feared that a *laissez faire* approach would result in a scramble for the best sites that would leave them out in the cold. Moreover, it would undercut the principle, which had been adopted by the General Assembly, that the seabed is part of the common heritage of mankind -- a global commons in which all countries have a stake. Somehow the benefits of deep seabed mining need to be shared. Yet the economics of the situation imply that benefits will only accrue to large-scale enterprises. Indivisibility results from increasing returns to scale, a situation that is in fact quite common.

The solution adopted by the Conference is an ingenious variant of the cake-cutting procedure. Two entities were established to supervise deep sea mining: an International Seabed Authority that licenses all mining activities, and an international mining company known as the Enterprise that mines the seabed on behalf of the developing countries. The rule is that every time a mining company applies to the Seabed Authority for permission to mine at a given location, it must develop *two* parallel sites from which the Enterprise gets to choose *one*. This process guarantees the Enterprise at least half the benefits from all developed sites.

Dividing an inheritance

Let us return to the level of the family and consider another situation involving indivisibles. Suppose that two heirs have been left equal shares of an estate that contains a valuable painting, say by Picasso. If they cannot agree on how to divide it, the matter will be referred to the courts and the lawyers will take their cut -- perhaps even the whole thing. Thus there is a strong incentive for them to negotiate a solution. What options are available to them? I shall suggest eight techniques for defining *ex ante* property rights in the indivisible good that are fairly universal.

1. Cut the painting in two. This is very wasteful.
2. Flip a fair coin to determine who gets it. Although decision theorists sometimes recommend this approach, it is quite uncommon in practice. The reason is envy and regret after the fact. You would rather not take a fifty percent chance that your sister gets sole possession of the painting.
3. Rotate possession : one month it hangs in one heir's apartment, the next month in the other's.
4. Hold the property in common, say on the stairway leading to their separate apartments.
5. Destroy it or give it away, say to a museum.
6. Sell it and divide the money.
7. Compensate the person who does not get the painting with something else, either money or another good (perhaps another painting). This amounts to expanding the pie -- more goods must be placed on the table.
8. Give it to the person who has the greatest claim to it, for example, the eldest, or the one who collects art. This is the *first-in-line* method, where place in line is determined by some criterion of priority or desert. This method is far more common than many people realize. It works whenever the criterion that determines priority is a widely-held norm. Primogeniture used to be such a norm; first come first served still is.

Three equity principles

These eight methods amount to different ways of defining *ex ante* property rights in the indivisible good. I shall call them the eight *modes* of dividing an indivisible. The choice of a mode does not, however, determine the actual shares that the claimants get. To say that we are going to hold a lottery among the claimants is not to say how many chances each claimant gets. To complete the solution we need to make two further choices.

First, we need to determine the *distributive principle* that best applies to the case. We may discern three distinct distributive principles. *Parity* states that the parties have equal standing and must therefore be treated equally. If the mode of division allows it, this means exact equality -- all parties get equal shares. In some situations, however, exact equality may not be possible or even desirable because the parties have different preferences. In this case parity calls for a rough form of equality in which everyone gets a portion that he likes at least as well as anyone else's portion.

The second fundamental distributive principle is *proportionality*. Allotments should be in the same ratio as the parties' differences, where differences (whether of contribution, need, or desert) are measurable on a cardinal scale. This principle can be implemented by most of the methods we talked about earlier, including lotteries, rotation, sale, and compensation. It is not consistent, however, with first-in-line or giving away.

The third fundamental principle is *priority*, which implements the first-in-line method. Many conceptions of priority are possible. It could be priority in time (who had the earliest claim), suitability (who can make the best use of the object), or need. Sometimes priority is determined by a combination of factors. In the United States, for example, kidneys are allotted to transplant patients by a formula that weights all three criteria -- time waiting in line, medical suitability, and urgency of the case (Elster, 1993; Young, 1994).

Notice that each of the above distributive principles can be applied in a variety of ways depending on what we think ought to count in determining the claims. In applying the parity principle we must decide what is to be treated equally: is it persons, or groups of persons -- say families or communities? To apply the proportionality principle we need to have a *cardinal* measure of differences among the claimants. This could be a measure of contribution, need, desert, or perhaps some combination of factors. Similarly, to apply the

priority principle we need an *ordinal* measure of difference -- some way of deciding who is the most needy, the most deserving, the most suitable, and so forth. Determining what normative criteria count is the final part of the problem

To summarize, the allocation of an indivisible good requires three different kinds of choices: the *mode* of division, which determines the ex ante form of the property rights; the *distributive principle* according to which the property rights will be divided (parity, proportionality, or priority); and the *normative criterion* (or criteria) that will be used to implement the principle.

Dividing a child

Which of these combinations is most appropriate depends on the situation at hand and on the preferences of the claimants. In dividing a work of art, for example, the usual modes of division would be sale or compensation. But when parents get divorced would they divide their child in the same way? Let's consider the eight modes applied to this case.

1. The child could be physically divided. This is what King Solomon threatened.
2. The parents could flip a coin to see who gets custody. This has been proposed as an alternative to lengthy court battles, which are not only expensive but may be emotionally harmful to the child (Elster, 1989).
3. Rotation or joint custody. This is one of the most common solutions to the problem. The parties need not share equally under this method. One parent might have the child on week-ends, for example, and the other have custody during the week.
4. Hold the child in common. This is what they were doing before they divorced.
5. Give the child away, say to a grandparent.
6. Sell the child.
7. Compensate the person who does not get the child with something else of value, say a summer house. (In fact the person who gets the child is usually awarded money for child support as well.)

8. Give sole custody to the parent who is most *fit* to raise the child. Determining fitness or suitability is what child custody battles are all about.

In the case of a child, then, rotation and first-in-line are the usual modes of allocation, whereas for works of art the customary methods are compensation and sale.

Application to international disputes

Virtually all eight modes have been used to resolve disputes in the international arena. Physical division is a common means of allocating disputed territory even when its value is thereby reduced. The division of Berlin is a prominent example. Allocation by lottery, though often recommended by theorists, is seldom used in practice. Nevertheless it is not without precedent. In the Bible God commanded the Israelites to divide their lands by lot (Numbers 26:55). In the 1947 partition of India and Pakistan, some common property was allocated by the toss of a coin, as I shall describe below.

Rotation is another common device for dividing indivisibles. Membership on the United Nations Security Council rotates among the non-permanent members. This method was also applied to the division of Vienna at the end of World War II. No walls were erected as in Berlin. Instead, each of the four occupying powers -- Britain, France, the United States and the Soviet Union -- had exclusive jurisdiction over one sector of the city. The central core (the area lying inside the Ringstrasse) was administered by a four-power council, whose chairmanship rotated among the members.

Another way of resolving territorial disputes is to hold the property in common. This is the case with Antarctica, which is claimed by a baker's dozen worth of countries: Argentina, Australia, Belgium, Chile, France, Japan, New Zealand, Norway, Poland, South Africa, the former USSR, the United Kingdom, and the United States. Instead of pressing their claims, they agreed in a 1959 treaty to use the continent only for scientific purposes and not to colonize it or develop its economic resources.

There are also cases where the parties have given up their claims to a disputed territory rather than go to the mat defending them. Once again Austria provides a case in point: instead of partitioning the country or going to war over it, the four powers withdrew in 1956 on the condition that it be permanently nonaligned. This is the giving-away method.

I do not know of an instance where two countries have actually sold disputed territory to a third party and split the proceeds. However, there are certainly cases where one has given up a territorial claim in return for compensation by the other. For example, under the Camp David Accord, Israel gave back the Sinai to Egypt in return for various concessions, including the important symbolic step of diplomatic recognition by Egypt. This is an example of expanding the pie.

First-in-line is another favorite method for resolving international claims. We take it for granted that priority of settlement establishes a *bona fide* claim to territory, just as we believe that arriving early at a ticket window establishes our priority to get tickets. What makes this work is that priority of arrival is a widely held norm; those who violate it are subjected to social disapproval. When someone cuts ahead of us in line, we express outrage even though the inconvenience to us is quite minor. Indeed this form of social pressure is necessary for the norm to remain in place.

Criteria of priority

Priority can be established in many other ways than order of arrival. For example, it is sometimes determined by *suitability* for the good in question, as in the award of child custody, the determination of who gets a kidney for transplantation, or who is admitted to university. This is also what King Solomon was up to in his famous first judgment. Two harlots came before him bearing a small baby, each claiming that the baby was hers. Solomon lifted his sword to cleave it in two, but at the threatened moment of execution one of the women cried out that she would rather give up her claim than see the child slain. Thus, in relinquishing her claim, the true claimant revealed herself. Suitability was revealed through a ruse.

The opposite case -- of losing one's claim by asserting it -- is also possible. I recently came across a nice example of this in the reminiscences of Elizabeth Hubbard, the daughter of a Harvard professor of botany, who tells some charming tales about growing up in Cambridge, Massachusetts in the early part of this century (Hubbard, 1988). The boy next door was the future poet e e cummings. One fine summer day -- when the children were about ten -- they decided to hold a parade. After much negotiation about the details of their attire and the order of events, it came down to the question of who would carry the American flag. Elizabeth asserted boldly that as she was a *lady* she

should carry it. He retorted, quite correctly, that *if* she were lady she would not have brought it up.

In the international arena, priority over territory is often established by date of discovery or settlement, but not always. Sometimes *proximity* is the crucial factor. Around the turn of the century a dispute erupted about who had sovereignty over the archipelago of Spitsbergen (Derry, 1973). Up to that time it had been regarded as *terra nullis* and had no indigenous population, though its waters were used by various countries for whaling. All of this changed when an American prospector by the name of Longyear discovered significant coal deposits and started to develop them commercially. Other firms jumped in as well. By the time of the First World War several countries were advancing claims on it, including Britain, Norway, The Netherlands, Germany and Russia.

None of them could claim first discovery, which had been made by Icelanders in the year 1194. Indeed, some of their claims were rather flimsy, resting mainly on their occasional use of the waters for whaling. It is true that several British firms had coal mining interests there, though they were relatively inconsequential. By this time the main coal producer was a Norwegian company that had bought out the American interests. Thus the Norwegians could claim the greatest economic investment. However, the decisive point was that Norway was the *closest* to the disputed territory. The other parties accepted this argument, and a 1920 treaty awarded Norway sole sovereignty. This example illustrates why parties may agree to a principle that seemingly awards them. The reason is that the alternative -- unresolved sovereignty and the prospect of conflict -- is much worse than getting nothing.³

Priority can also be established through *need*. In 1982, the International Whaling Commission, concerned about steep declines in whale populations, imposed a ban on almost all whaling pending a comprehensive assessment of whaling stocks. However, the Alaskan Inuits, for whom whales are one of the principal sources of food, were allowed to continue their traditional hunt (Van Beek, 1987). In theory the same number of whales could have been allotted *pro rata* among all the whaling countries, but this would have made little sense. A handful of whales for Japan or Russia would be as good as none at all. Instead, they were awarded in a lump sum to the claimants with the greatest need.

³ The year 1920 was a propitious moment to settle the matter, as the claims of Germany and Russia could effectively be ignored.

Mixing the methods

A division of common property that illustrates almost all of the above methods was the Partition of India and Pakistan in 1947. Never in history has there been such a complicated divorce. On the stroke of midnight August 15, 1947 the raj came to an end and two new countries were born. The magnitude of the enterprise was unprecedented. Some four hundred million people and a territory the size of Europe was split in two. All government property was divided between India and Pakistan according to principles that they had jointly negotiated. This included bullion in the bank, railroad engines and cars, desks, chairs, books, brooms, typewriters, hat pegs, paper clips, and chamber pots. In charge were two lawyers -- Chaudhuri Mohammed Ali for Pakistan and H. M. Patel for India -- plus a staff of a hundred bureaucrats who kept handwritten stacks of files, each knotted with a twist of red ribbon (Collins and Lapierre, 1975).

As in most divorce cases, some of the bitterest disputes were over money. Patel and Mohammed Ali had to be locked into a bedroom until they came to terms. The outcome was that all cash in the bank and government debt was apportioned in the ratio 17.5% for Pakistan, 82.5% for India, this being roughly the proportion of population in the two countries. All other divisible assets -- tables, chairs, typewriters, telephones, army uniforms, brass bands -- were divided in the proportions 20% for Pakistan and 80% for India. (This represented a simple rounding of the monetary criterion.) But some property was not strictly divisible. A notable case was the national libraries. Some books were simply ripped in two; Pakistan got A-K and India L-Z of a dictionary for example. Sets of encyclopedias were divided with alternate volumes going to each dominion. When only one copy of a book was available, a team of librarians was charged with deciding which country had the greatest natural interest in it. People actually came to blows over such questions as whether India or Pakistan had a greater natural interest in *Alice in Wonderland*. (Notice that this is the priority principle in action, where the criterion is suitability.)

One of the most fascinating episodes took place in the stable yards of the Viceroy, Lord Mountbatten. At issue were twelve viceregal carriages, six trimmed in gold, six in silver. They represented all the pomp, majesty, and mystery that had both fascinated and infuriated the raj's subjects. Every visiting dignitary and head of state had paraded through the streets in one of them. Mountbatten's aide-de-camp, Lieutenant Commander

Peter Howes, decided that it would be a shame to split up the sets. Instead, they would settle the matter by lottery. He tossed a coin into the air. Major Singh, the Indian representative, shouted "heads." Heads it was, and India took the gold coaches. Lieutenant Howes then proceeded to divide up all the boots, wigs, uniforms, and other paraphernalia that went with each set of carriages. One item, however, remained: the coachman's ceremonial posthorn. The obvious solution was to toss a second coin. Howes hesitated: if India won the toss again, the Pakistani representative who was already fuming, might boil over. Instead, he announced that he would give it to neither, and sauntered out of the courtyard with the horn tucked under his arm.

A significant feature of this case is that the solution was mixed: different types of property were allocated according to different modes, different principles, and different criteria. Homogeneous property was physically divided according to the proportionality principle, with population shares as the criterion. Some of the books were divided equally, others on the basis of suitability (first-in-line method, priority principle). The viceregal coaches were allocated by the toss of a coin (lottery method, parity principle). The posthorn was taken away (parity again). Perhaps the most important indivisible -- the name India -- was retained by the larger half on the grounds that the smaller half (Pakistan) was seceding. Once again this is an application of the priority principle.

Gains from trade

Could this division have been improved upon? Certainly one can do better than tearing dictionaries in two. There was a similar case not long ago when the University of Louvain in Belgium separated into two universities along linguistic lines. The old campus of the university became exclusively Flemish and was styled the Catholic University of Leuven. A new campus was built nearby for the French-speaking contingent, and called the Universite Catholique de Louvain.

As in the India-Pakistan partition, a major bone of contention was how to divide the library. Should they, like the Indians and Pakistanis, rip the books in half? A more sensible solution would be to give the Flemish books to the Flemish campus, and the French books to the new French one, with a separate principle used to allocate books in other languages. Yet they did not follow this method either, perhaps because the two collections differed in size. Instead, they went down each shelf and gave alternative volumes to each campus -- one to Leuven, one to Louvain, the third to Leuven, and so

forth. Needless to say, this was extremely wasteful, as it meant splitting up sets of encyclopedias and bound journals. However, there was a second stage of the process: the parties were allowed to trade. Half of one set of journals was swapped for another to make two complete sets. Flemish books were traded for French ones, and so forth. Although this process was time-consuming, one could argue that it was worth the effort because it produced an outcome that was both equitable and efficient. Equitable because it began from a position in which both parties started with more or less equal shares. Efficient because, after trade, not both parties could do better.

Siting hazardous facilities

Let me switch now to a discussion of indivisibles in the environmental arena. I have already mentioned the atmosphere as an example of an indivisible whose use is going to be increasingly regulated and divided in the years ahead. Another problem of indivisibles that almost all countries face *within* their borders is where to locate hazardous waste dumps. In the United States, for example, a debate has raged for years about where to put spent nuclear fuel and weapons materials. Though several sites have been identified as feasible on technical grounds, it has proved to be politically infeasible to implement any of them.

What makes the allocation of waste disposal sites so difficult is that we think of it as a zero-sum game. If it is not in your backyard then it must be in mine. Like the other cases we have considered, however, waste disposal sites are not really indivisible. We could have every community or even every home dispose of its own wastes in its own backyard. Foolish as this arrangement may seem in some ways, it is reasonably fair in that it places the burden directly on those responsible for creating it. The reason we do not take this solution seriously it is that it is so inefficient. As noted earlier, this is the case with almost all indivisibles: they actually are divisible; what we mean is that they lose much of their value by being divided. Or in this case by being multiplied.

Let's consider the eight ways by which we could divide hazardous waste sites.

1. Divide the waste among all communities in proportion to their population, or perhaps the amount of waste they produce. (This is the proportionality principle applied to physical division with waste generation as the criterion.)

2. Lottery: flip a coin to decide which community receives it. One could restrict the lottery to those sites that meet certain technical criteria of risk and cost. It could be an equal-chances lottery, or perhaps the chances could be pro-rated to the amount of waste each community generates.

3. Rotation: require everyone to live near the waste dump some of the time.

4. Hold the waste in common. This is more or less the current situation in the United States, where hazardous wastes are stored temporarily in railroad cars, which are shunted around the country pending a "final" solution to the problem. This could be called fair since most people are (unwittingly) exposed some of the time, but it is quite unsatisfactory since it probably exposes the population to greater risk than necessary.

5. Give it away. For example, load the waste onto rockets and shoot them into outer space. (One would have to find a criterion for dividing the cost, however, so this is not a pure form of giving away.)

6. Pay someone else to take it. This idea gained some notoriety when Lawrence Summers, then chief economist at the World Bank, proposed that the comparative advantage of poor countries is to store the wastes of the wealthier industrialized countries. Since the former need the money and the latter don't want the refuse, this is a classical gain from trade. ⁴

7. Compensation. This option is widely discussed in the literature on hazardous waste siting. In one version, there is an auction to determine who is most willing to accept the dump (i.e., who bids the least amount of money as compensation to accept it) and the other communities divide the cost (Kunreuther et al., 1987). In other versions the host community is compensated with public works projects, such as a new school or a hospital.

8. Priority. One option is to locate the waste dump on the basis of technical suitability, for example, where it will cause the least ecological damage. Or it could be put at the site that costs the least to build. Alternatively, a combination of factors could be used to rate

⁴ The Guardian, February 2, 1992.

the suitability of different sites. This is the standard approach in the United States and in much of western Europe.

How are we to decide among these options? To begin with, there is merit in recognizing that options exist. It provides something concrete for the parties to negotiate about. Nor does the introduction of options necessarily lead to stalemate and confusion. For example, it is entirely possible that *all* parties would prefer some methods of division to others. In hazardous waste siting, it seems likely that everyone would prefer a scheme in which the loser is compensated in kind (and everyone has some small chance of being the loser) than a situation in which everyone is constantly exposed -- this being the outcome if they cannot agree to a solution. By putting all the options on the table, one makes it clearer to the claimants what their fallback position is, and this in itself may goad them into making substantial compromises.

Public participation

Of course there are some kinds of disputes where it may be difficult if not impossible to get all the affected parties around the table. This is probably true of hazardous waste siting. Nevertheless, it is highly desirable to give the parties *some* sense of participation in the decision process, since participation is connected with people's willingness to accept the outcome (Deutsch, 1975).

One approach is to solicit the views of representative stakeholders through public opinion polls. A study of this sort was recently carried out by IIASA in connection with a siting dispute in Austria (Linnerooth et al., 1994). At issue is where to locate a hazardous facility for storing toxic wastes that are generated in Vienna and Lower Austria. A panel of experts recommended two sites -- Enzersdorf and Blumau -- on the basis of technical considerations. When the report was published there was a major outcry from the villagers (and quite a few other Austrians) that the selection process, which had been shrouded in secrecy, was inherently unfair.

The project at IIASA polled members of the general public, environmental professionals, students, company leaders, and residents of Enzersdorf and Blumau to determine their

attitudes toward various solutions. Among other things they were asked to compare the following different modes of division: ⁵

i) *physical* -- spread the risk by siting facilities in five qualifying communities, even though this would be more expensive than a single site;

ii) *lottery* -- if several communities are more or less equally qualified, choose among them by an equal chances lottery;

iii) *sale* -- pay another country to take the waste;

iv) *compensation* -- a) money: determine who will accept it at the least cost
b) in-kind (e.g., a new hospital)

v) *first-in-line* -- select a single site on technical grounds (health risk, geological suitability, ecological damage)

Seventy percent said that it would be better to have one site than five sites. *Sixty-two percent* said that a lottery would not be appropriate. *Eighty-four percent* said that sale to another country would not be appropriate. *Sixty-seven percent* said that an auction to determine willingness to accept would not be appropriate. However, *ninety-three percent* said that *some* form of compensation would be appropriate (a majority favored in-kind). First-in-line -- with technical suitability as the criterion -- also received majority support with *fifty-three percent*. These results suggest that there is greatest support for selecting the community on technical grounds and providing it with in-kind compensation.

This conclusion is amplified by a second part of the study, which asked the sample group was asked to compare the importance of various normative criteria on a scale from 0 to 3. The average importance weights assigned to the most significant of these criteria are shown below (positive scores qualify the community for the site, negative scores disqualify it):

⁵ The questionnaire did not deal with three other modes -- rotation, holding in common, and giving away -- that do not make much sense in this context.

Conclusion

What lessons can we draw from this discussion? First, indivisibles are not really what we say they are. We can divide them, but they lose much of their value when we do so. The challenge is to devise ways of dividing property rights in the indivisible good that preserves as much of its value as possible while treating all claimants fairly. We identified eight methods for doing so -- physical separation, lotteries, rotation, holding in common, destroying or giving away, sale, compensation, and first-in-line. Each of these methods can be elaborated in various ways. Holding in common, for example, requires a precise delineation of the property rights each claimant has on the object. Compensation forces them to consider how they might expand the pie. These options cannot be carried out mechanically; they require a lot of thought and ingenuity.

Second, the parties must decide which of the three equity principles -- parity, proportionality, priority -- most naturally applies to their situation. Third, they need to determine what criterion (or combination of criteria) are appropriate to implement it. Sometimes they will conclude that a *combination* of approaches best meets the claims of everyone concerned, as in the partition of India and Pakistan.

Finally, they need to consider whether they want to trade after the initial allocation. Trade recaptures part of the value lost in the division, so it is usually a good idea. But not always: most people would probably think it inappropriate, for example, to allow patients who are high up on the waiting list for kidneys to sell their place (or the kidney they get) to someone further down the line. For much the same reason we would prevent someone who got into university on the merits from selling his place to someone who failed to get in. In these cases the indivisible good is awarded on the basis of merit, and society has an interest in the good being used by the person to whom it was assigned.

I have presented a variety of examples -- the Spitsbergen Treaty, the Partition of India and Pakistan, the Law of the Sea, the Montreal Accord, the Clean Air Act, the International Whaling Agreement -- to illustrate how these ideas play out in practice. Nevertheless the skeptic may ask: how do we *know* that the outcomes of these negotiations were just?

At the simplest level we could say that they are just because the parties willingly agreed to their terms. No one was coerced. This is not a completely satisfactory answer,

however, because it is not falsifiable. Under this definition of equity, the outcome of *every* voluntary agreement is fair. It is rather like saying that individuals always make choices that maximize their utility functions. Without saying what properties utility functions have, it is not a useful statement.

In fact we can say a good deal more. The justice of the agreements we have analyzed is evident from their *terms*. These are not arbitrary, but follow definite patterns and employ well-established principles that we see in many other distributive situations. The three fundamental principles of equity are parity (which applies when the claimants have equal standing), proportionality (which applies when their claims are comparable but different), and priority (when even a small difference is decisive). In each of the cases discussed above these principles were interpreted differently in the details, but they were clearly recognizable.

Finally, it is important to recall that these agreements worked. They proved to be durable and averted conflict. Moreover, they remained in place without the benefit of strong institutions to enforce them. This is a significant fact. I doubt that they would have had the same self-policing property if their terms had been more or less arbitrary -- the outcome of a contest of wills with no rationale to back them up. Agreements based purely on bargaining power are fragile. In the first place they are almost impossible to justify to one's constituents. The representatives for Louvain and Leuven will have little trouble justifying a 50:50 division of the books, but a lot of trouble justifying .56 : .44. It is not good enough to say that the outcome resulted because Leuven did not bargain as hard. Similarly, the representative from Pakistan can say that he agreed to a 20%-80% split because this is the approximate ratio of the countries' populations, but he cannot say he agreed to it because Pakistan was in a weaker bargaining position. It may be true but it is not an acceptable reason. Moreover the Indian representative knows this. Hence they both have an interest in crafting an outcome that is based on widely-accepted norms and can be justified to their constituents. This fact severely constrains what they can agree to.

Even if the parties are *not* answerable to their constituents, however, there is an advantage to basing an agreement on distributive norms rather than on balance of power arguments. The trouble with power is that it cannot be known precisely and perceptions of it are constantly in flux. An agreement reached on this basis today may well have to be renegotiated tomorrow, which is not an attractive prospect. It is better to come to terms on the basis of principles that do *not* change from one day to the next, for then the

agreement is self-policing: if the parties have to renegotiate, they can expect to come to the same terms they did before. This is why negotiations based on equity principles are so attractive -- they strike a balance that the parties find satisfying when the agreement is made, and that they continue to find satisfying over time.

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