

ESTABLISHING PROPERTY RIGHTS IN OUTER SPACE

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One way or another, the world seems headed toward a legal order to allocate the increasingly scarce and valuable geosynchronous orbits. . . . Only with a wider sense of shared commitment and less national insecurity will the world be able to enjoy the full benefits of space.

—Daniel Deudney

Introduction

Space is a resource. With the advent and proliferation of space travel, particular locations in outer space are rapidly becoming scarce resources. The demand for satellite systems has grown rapidly during the past decade. Such growth in demand follows the development of new satellite launch systems and reductions in the costs of these systems. With the commercialization of launch services, satellite technology is rapidly becoming less costly to obtain. NASA's Space Shuttle, the European Space Agency's Ariane rocket, and NASA's Atlas Centaur and Delta rocket systems (both soon to be privately controlled) are now competing for public and private customers.¹

There has concurrently been an increased awareness of the benefits to be gained from an unmanned presence in outer space. Com-

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¹NASA has selected Transpace Carriers Inc. of Greenbelt, Maryland, to be the private marketer of launches on the Delta rocket. NASA is also negotiating with General Dynamics to become the marketer of the Atlas-Centaur launch system.

munications satellites have revolutionized worldwide telecommunications. Weather satellites provide near-instantaneous updates on weather conditions. Reconnaissance satellites provide continuous monitoring of military activities in foreign countries. Teleconferencing services via satellite and direct delivery of television programming to residential areas are becoming commonplace.

The economic benefits from satellite technology are large. But although the demand for satellite systems is rapidly increasing, the orbital paths into which the satellites can be placed are limited. These paths represent a scarce resource because they are desirable but limited. Scarcity implies the need for resource allocation among unlimited human wants—the fundamental problem of economics.

The issue addressed in this paper is the allocation of the limited and desirable physical locations in outer space for geosynchronous satellites. How will these scarce resources be allocated? Can they be efficiently allocated? If peaceful and efficient coexistence in space is to prevail, then the creation and enforcement of property rights is inevitable.

The Problem: Geosynchronous Satellites

A geosynchronous satellite is one that is placed in a west-to-east orbit over the earth. The satellite is placed at an approximate altitude of 22,300 miles, where its period of revolution around the earth is 24 hours. The orbital movement of the satellite is synchronized with the earth's rotation so that the satellite appears from particular points on earth to remain stationary. Continuous transmission of information can be attained between those points. Electronic channels, known as transponders, are built into the satellite and receive, amplify, and retransmit microwave signals sent from earth.

Technical Aspects of the Scarcity Problem

The physical locations in space where geosynchronous satellites can be placed are limited. To fully appreciate why this is true, it is necessary to understand the technical characteristics of satellite systems—specifically, the limitation of the number of radio frequencies for transmissions and the required spacing of satellites in geosynchronous orbit.

Satellite systems consist of several primary components: the satellite in geosynchronous orbit, the on-board transmission system, and the earth-based antenna and transmission station. Satellite broadcasting relies on the use of the radio-frequency spectrum. Different types of transmissions have different bandwidth requirements within

the spectrum. For example, voice and data transmissions require only small bandwidths within the spectrum. Television transmissions have much more extensive bandwidth requirements. The number of bandwidths, however, is limited. It is possible for many satellites to use the same frequencies for their transmissions, but satellites must nevertheless be spaced sufficiently far apart from other satellites using the same frequency in order to guarantee that interference in transmissions will not occur. The spacing requirement is sensitive to the available power supply on board the satellite and the size of the earth-based antennae. Current technical considerations require that each satellite be placed approximately 2–3 degrees away from any other satellite using the same transmission frequencies. This means that a maximum of 180 orbital “slots” would be available to satellites using the same frequencies and occupying the same 360-degree orbital path.

The usefulness of available orbital slots is further limited because not all slots are equally suitable for particular regions. In particular, the orbital arc over the equator north or south of the region to be served is the most valuable. These orbital arcs generally fall between the longitudes of the major continents. Consider, for example, the arcs of the orbital paths that are of greatest interest to the United States, Canada, Mexico, and Latin America. The orbital arc of interest to the United States lies between 60 and 135 degrees west longitude because satellites in this area can serve the entire continental United States. Satellites in the western 20 degrees of the arc can also be seen from Hawaii and Alaska. But this same 75-degree arc is optimal for satellite communications in Canada and Mexico. The eastern portion of the arc also contains the optimal locations for Latin America. But with spacing of 2 degrees, only 38 communications satellites using the same transmission frequency can occupy this 75-degree arc.

Congestion is inevitable if the demand for stationary satellites continues to grow. Some of the orbital arcs over parts of the equator south of Europe and North America are already crowded. INTEL-SAT, the international telecommunications satellite organization, projects that slots in some orbital arcs will be filled by the early 1990s (Deudney 1982).

The technical aspects of satellite transmissions, therefore, lead to two significant questions about the limited availability of orbital slots for geosynchronous satellites: (1) Are the existing frequency allocations that are in the desirable portions of the radio-frequency spectrum adequate, given the expected demand for satellite systems? (2) Even if the number of frequency allocations were adequate, would the number of orbital slots be sufficient?

Offsetting Effects

Although such technical constraints as frequency availability and spacing requirements contribute to the allocation problem, several other technical factors help mitigate the problem. First, the 2-degree spacing requirement applies only to satellites that use the same radio frequencies. In practice, satellites that use different frequencies can be placed adjacent to one another. In this case, the spacing requirement is reduced to the minimum distance deemed necessary to ensure that the satellites do not collide. (The FCC currently requires spacing of only one-tenth of a degree to reduce the probability of a collision.)

Second, using existing technology, it is possible to have satellites focus their transmissions into small geographic areas. As radio technology improves and the area of focus is reduced, the possibility of signals from adjacent satellites overlapping will be reduced, even if the transmissions are on the same frequencies. As the diameter of radio beams is reduced (for example, by using laser beams), the required spacing between satellites will also be reduced, thus increasing the capacity of any geosynchronous orbit.

Finally, a single satellite communications system cannot transmit and receive signals on the same frequency at the same time because interference will occur. Each satellite must therefore use at least two frequencies to receive and transmit signals to earth. But the capacity of the geosynchronous orbit can be doubled by having a second communications satellite in the same orbit use the same frequencies but for transmissions in the opposite directions (Martin 1978).

An Economic Description of the Problem

Congestion in Space: A Failure to Assign Property Rights

Private property does not yet exist in outer space. In fact, steps have been taken on the international level to prevent its establishment. In 1967 the U.N. Committee on the Peaceful Uses of Outer Space, which is responsible for legislating all matters dealing with space, drafted an Outer Space Treaty.² Ratified by 107 member nations, the treaty provides the current framework for space law. The central principle underlying the treaty is that outer space is not subject to appropriation by any one country; all nations have equal rights and access to the resources of space. Outer space is the "province of all humankind" (Cowen 1985). The treaty's failure to establish property rights is critical. Congestion in geosynchronous orbits will worsen

²The title of the draft is "Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies."

in the absence of property rights. The price of an orbital slot is zero, so that entry into synchronous orbit is free.

The argument for establishing property rights in outer space is an application of what McCloskey (1985, p. 330) has called Adam Smith's generalization: If transactions costs are low, the assignment and voluntary exchange of rights to scarce resources will result in an efficient allocation. Conversely, the failure to assign property rights to the scarce resources will inevitably lead to an inefficient use of the resources.³ The problem is a common one in economics. Consider, for example, the overhunting of the buffalo on the Great Plains. The opportunity cost of hunting the buffalo, in terms of yet-to-be-born buffalo, was zero. They were overhunted and killed almost to the point of extinction because no one owned them. The few remaining buffalo survived only because laws that established property rights to the remaining buffalo and their unborn offspring finally protected them (McCloskey 1985, pp. 330–31).

As applied to outer space, Smith's generalization implies that an efficient use of scarce orbital slots will result once property rights are assigned unambiguously to a particular country (or coalition of countries) and free exchange is permitted so that the country can sell the property rights for whatever the market will offer. A common counterargument is that the nations of the world, operating in their own self-interests, will conserve the orbital slots even in the absence of well-defined property rights. But this argument is mistaken: if the price of an orbital slot is zero and the orbital paths are not owned by anyone, the opportunity cost to any one nation of occupying these locations is lower than if property rights were assigned. Orbital paths for geosynchronous satellites will be overused by individual countries and congestion problems will worsen. External costs to firms and nations that may want subsequently to occupy these orbits will not be fully taken into account. The problem is one of ownership.

The Inevitability of Property Rights in Outer Space

Economic theory suggests that property rights will be created when it is in someone's self-interest to do so. Demsetz (1967) has argued that the emergence of property rights takes place in response to the desires of individuals (or governments) for adjustment to new cost-benefit possibilities. According to Demsetz (p. 350): "Changes in knowledge result in changes in production functions, market values, and aspirations. New techniques, new ways of doing the same things, and doing new things—all invoke harmful and beneficial effects to

³This principle is often referred to as Coase's theorem in the literature (see Coase 1960).

which society has not been accustomed.” The advent of satellite technology and communication was a major technological change. New markets were created—markets to which old property rights were no longer applicable—and the relative prices of the different techniques changed dramatically.

The emergence of property rights as a result of the new technology has been a gradual process. During the early days of space exploration, the United States and the Soviet Union were the only nations that possessed the technology to place satellites into geosynchronous orbit and relatively few were launched. Since orbital locations for synchronous satellites were limited and only a few satellites were launched, it did not pay for anyone to be concerned with the allocation of orbital slots. Property rights were not defined. The development of new satellite technology and more sophisticated and cost-competitive rocket delivery systems has increased the rate at which orbital slots are being filled. The value of the synchronous orbital paths, therefore, has increased.⁴ Property rights to the orbital slots will be established as it becomes worthwhile for interested nations to be concerned with the establishment and allocation of such rights. A set of economic and social relations specifying the rights of each country to use the orbital slots will be created in order to allocate these scarce resources in specific and predictable ways.

The issue is scarcity, and the particular locations in space that must be occupied by geosynchronous satellites are scarce. They must somehow be allocated. The market will ensure that property rights to the scarce orbital slots are defined and enforced.

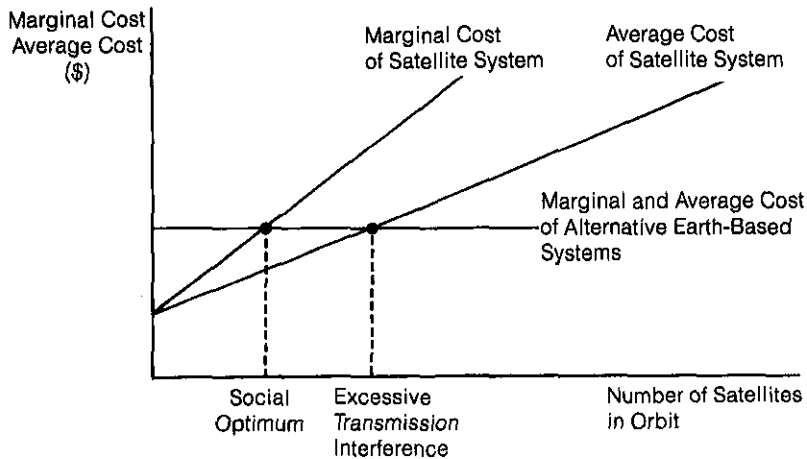
Private Property Eliminates Congestion

Congestion of orbital slots is the result of an absence of ownership. Consider the case of a country that has decided to invest in a satellite communications system rather than, say, a ground-based microwave transmission system. When that country's satellite is placed in geosynchronous orbit, it adds to the congestion problem and increases the possibility of transmission interference or collision with another satellite. Although the external effect on each individual satellite in the orbit is small, the total effect on all satellites is large. The country launching the new satellite, however, does not consider the total external effect on all satellites; that is, it does not consider the social cost of one more satellite being placed in orbit. It only considers the

⁴A market analysis by Batelle Laboratories of Columbus, Ohio, predicts that the different launch systems will be competing for 400 to 700 commercial payloads from now through 1998.

average cost (or cost per satellite launched) it faces—that is, the private cost of the satellite system. Each individual country acting alone, in its own self-interest, will not make socially correct decisions when the orbital slots are not owned by anyone. This misallocation due to the lack of well-defined property rights is illustrated in Figure 1.

FIGURE 1
THE SOCIAL OPTIMUM



Under the status quo, orbital slots are not owned by anyone and the price of a slot is zero.⁵ A country that is contemplating placing a communications satellite into a geosynchronous orbit will only consider the average cost of the system. It will choose the satellite system over the alternative ground-based systems until the average cost of placing satellites in orbit is equal to the marginal cost of the alternative systems.⁶ Satellites will be placed in orbit up to the point where the average cost of the satellite system (the private cost) is equal to the marginal cost of alternative, uncongested systems. Although this is an optimal private decision, it is inefficient for society. The social optimum is obtained when investment by different countries in satellite systems is allocated so that the marginal cost of the earth-based systems is just equal to the marginal cost of the satellite system.

⁵It is interesting to speculate whether country A could, with legal impunity, knock country B's satellite out of an orbital path that A wishes to occupy. It would appear (as is later discussed) that there is a set of de facto property rights established on the basis of a first-come, first-served allocation scheme.

⁶The marginal cost of an alternative system is equal to the change in total cost that occurs when one more ground-based system is built.

The social optimum, of course, is unknown *ex ante*; rather, it will tend to emerge once private property rights to orbital slots are assigned and enforced. By assigning property rights, a market is established in which the rights to the orbital slots may be bought and sold. Selfish maximization of the profit from property rights will lead to a socially efficient outcome. The negative externalities will be eliminated. The owner of a right to an orbital slot will charge a positive price for the slot that maximizes his net revenue. This price will be the one that induces countries to recognize the costs they impose on others by adding to the congestion of satellites.

If all orbital paths are owned and transactions costs are low, an efficient outcome will prevail. It does not matter which country initially obtains the right to a particular orbit. If exchange is costless, the right will eventually be owned by the country that values it the most. As Cheung (1970, p. 64) noted:

Competition for and transferability of the ownership right in the market place thus perform . . . main functions for contracting. . . . [C]ompetition conglomerates knowledge from all potential owners—the knowledge of alternative contractual arrangements and uses of the resource; and transferability of property rights ensures [via flexible relative prices] that the most valuable will be utilized.

If the market is allowed to operate, then an efficient (although not necessarily equitable) outcome will prevail.

A classic example of the importance of private property for achieving a socially efficient use of resources is the distribution of property rights in the United States to radio and television frequencies (Coase 1959). In the 1920s there were no restrictions on who could broadcast on any frequency. Chaos ensued. Consequently, the courts adopted a first-come, first-served method of allocating frequencies. The first user of a frequency had ownership claims to it. In general, this type of allocation scheme did not result in frequencies being owned by those users that valued them the most. Nevertheless, if the rights to the frequencies could have been traded, an efficient outcome would have prevailed. A redistribution of wealth would have occurred in favor of the initial owners of the frequencies, but the final allocation would have been efficient. The U.S. government, however, chose to allocate the frequencies according to its own criteria.

Alternative Systems of Allocation

The Historical Record

The historical record of attempts to resolve the congestion problem is not encouraging. The international community recognizes that a

problem exists, but agreement on its resolution has been difficult because of differences in national objectives and in the present endowments of technology and wealth. The United States and the Soviet Union both recognize the need for international agreement on an allocation scheme. They also recognize, however, that such an agreement might force them to share satellite technology and give up orbital slots to Third World nations. Orbital slots have thus far essentially been allocated on a first-come, first-served basis.

The United Nations' International Telecommunications Union (ITU) currently attempts to allocate the slots among countries. But the ITU's judgments are not enforceable, and not all countries recognize its jurisdiction. Many Third World nations view the rapid appropriation of orbital slots as an inequitable and inefficient distribution of resources. Developing countries oppose the allocation process because they believe many of the slots will be filled by the time they can use the satellite technology. The United States supports the allocation scheme and argues that the orbital slots really are not scarce; that technological innovation will improve transmission systems and increase the capacity of the orbits. However, a congestion problem *already exists and an efficient system of property rights needs to be put in place now.*

Several countries have opposed the U.N. Outer Space Treaty and the notion that outer space is not subject to national appropriation. In 1976, seven equatorial countries (most directly affected by the most desirable orbital slots) signed the *Bogota Declaration*, staking a claim on the orbits directly over their countries. They argued that because geosynchronous satellites are in a stationary position over their countries, the orbits are an extension of their territorial space. Although this declaration directly conflicts with the Outer Space Treaty and is not recognized by most other countries, the question of where national airspace becomes international space has not been resolved.

More recently, India has proposed a licensing system for the orbital slots. The proposal calls for each country to be awarded a certain number of slots. These licenses could then be bought and sold. The advantage of this system is that it would permit the use of the orbits now and would also provide *minimum property rights to developing countries.*

Economists will recognize in these conflicting attitudes and proposals the fundamental conflict between efficiency and equity. Systems of allocation exist that will inevitably lead to efficient outcomes. There are few disagreements over the efficiency or inefficiency of

these systems. The major source of contention is over the equity of alternative allocation schemes (Scheraga 1986a, 1986b).

Types of Ownership and Enforcement Costs

Various types of ownership are possible, including communal ownership, private ownership, and state ownership (Demsetz 1967). It has already been demonstrated that communal ownership of geosynchronous orbital paths is not feasible. Individual users of satellites do not have an incentive to limit the rate at which they occupy the orbital paths. Although, in theory, it is conceivable that the "international community" could jointly own these rights, the costs of reaching such an agreement would be very high. The costs of negotiation would be high because it would be difficult for countries to reach a mutually satisfactory agreement. This situation is aggravated by the unequal distribution of wealth, technology, and satellite launch capabilities. Even if an agreement could be reached, the costs of monitoring and policing it would be high.

The property rights, therefore, must be either privately or state-owned. Since the market for satellite technology and launch systems is international in scope, agreements on the definition and ownership of the property rights must be made at the international level. Governments must negotiate the allocation of orbital locations and agree on different allotments. The ITU has, in fact, attempted to administer geosynchronous orbits through international meetings and negotiations, but the union does not recognize the competitive market mechanism as a means of allocating the slots. Under the current nonprice allocation scheme, then, the ITU holds the market price to zero and allows political competition to determine who gets the available slots.

It is likely that if an individual government recognizes private ownership, the allotment will somehow be placed in the hands of private entrepreneurs. (Within the United States, the Federal Communications Commission has the responsibility of allocating orbital slots to commercial users.) Alternatively, if private ownership is not recognized, then the rights will be state-owned. It is essential for the efficient distribution of these property rights that the cost of exchanging the rights be low relative to gains from trade. In this case (neglecting the effects of the distribution of wealth on the valuation of orbital slots), it does not matter who initially obtains the orbital property rights. After negotiation and exchange, the rights will end up in the hands of those countries and firms that value them the most.

The result of private ownership of the property rights will be to internalize many of the external costs associated with communal

ownership. Each private owner will have an incentive to use his resource efficiently and to take into account the value of the property right.⁷

Alternative Allocation Schemes

The current method of allocation does not achieve an efficient or an equitable outcome. Under this system, the orbital slots are not owned, and there is no incentive for countries—especially those with large endowments of technology and wealth—to conserve the slots by restricting their use. The nonexistence of property rights has led to a congestion problem. If the slots were owned, the resource would be better used. Given that the existing system is not efficient, what alternative methods of allocation would be preferable?

A Bidding System. Adam Smith's generalization states that an efficient outcome will prevail if all orbital slots are owned and transactions costs are not prohibitive. This general principle provides a compelling argument for a simple bidding system—that is, a free-market economy in which mutually beneficial exchanges can occur.

The difficulty with an auction market is that the wealthiest countries would obtain most of the property rights and therefore would affect the outcomes of future trades between countries. A deal between any two countries must yield for one country a higher level of utility than before the trade and leave the second country no worse off, if the deal is to be mutually acceptable and is to take place voluntarily. But the extent of mutually beneficial trades will depend on the initial endowments of the two countries. It is therefore important to question the equity of the initial distribution of orbital slots.⁸ (Of course, if an auction system did exist and the price of slots was relatively low, the equity issue would no longer be a serious concern.)

⁷The right of ownership consists of the right to use a scarce orbital slot, to sell all of the rights to the slot, or to transfer some of the rights through rental of satellite services. The property rights to transponders on individual, privately owned communications satellites are already being sold. For example, AT&T leases transponders on its Comstar D-4 satellite to other telecommunications corporations. Hughes Communications Services Inc., a subsidiary of Hughes Aircraft Co., intends to lease to the Navy, for military communications, a satellite launched from the space shuttle Discovery.

⁸The Indian proposal for a licensing system hints at a solution to the equity problem. A more sophisticated organization or international agreement would have to be set up to award, with equity considerations in mind, a certain number of orbital slots to each country. Once the licenses were distributed, countries could trade and an efficient outcome would prevail. The problem with this system is the difficulty of getting all countries to agree on the initial distribution of slots.

The International Court of Justice. As suggested by the Bogota Declaration, questions of international law enter into the allocation problem. As the judicial arm of the United Nations, the International Court of Justice, or World Court, has the authority to rule on the legality of claims to the orbital slots. But only 44 of the U.N.'s 159 member states recognize the World Court's jurisdiction, and a majority of the 44 nations attached reservations to their acceptance. Further, the United States and the United Kingdom are the only permanent members of the U.N. Security Council that have accepted the Court's jurisdiction. The World Court has no practical way of compelling any nation to comply with its rulings. The Court is also highly politicized, so that an objective ruling about slot allocation could not be expected.

The seven equatorial countries that signed the Bogota Declaration did so in the belief that their claim of ownership was founded in international law. If the rulings of the World Court were truly binding, the equality of such claims would depend on these rulings. It is doubtful, however, that such rulings could ever be enforced. Despite the World Court's inability to enforce rulings on the initial distribution of orbital slots, Adam Smith's generalization still applies: if exchange is costless, countries will still bid for and trade orbital slots until they end up in the hands of those countries that value them the most.

Quotas and Licensing. Another approach to the allocation problem is to introduce quotas on the number of satellites each country can place into orbit. By international agreement, each country would be permitted a fixed number of satellites. The trading of rights to the slots would not be permitted. Quotas on the output of satellites by any country would be similar to quotas imposed on commercial airlines.

Quotas are licenses that have value. They bestow on some lucky few the privilege of earning rents from the orbital slots. A quota system would only coincidentally lead to an efficient and equitable outcome, however. A quota is a special case of a restriction on entry into a market, and restrictions usually lead to inefficient outcomes.

A Congestion Tax. If it is too costly to enforce property rights in outer space—that is, if transactions costs are prohibitive—what should be done? Two extreme solutions are to ban entry into geosynchronous orbit (which is unenforceable) or to permit unlimited entry into orbit (essentially the status quo). But these two extremes are inferior to a congestion tax, a solution most economists also prefer over quotas. A tax on each geosynchronous satellite could be imposed that

brings the marginal private cost of the system into equality with the marginal social costs. The size of the tax should reflect the amount of money that other countries would be willing to pay to prevent further congestion of the geosynchronous orbit.⁹ The congestion tax, therefore, becomes a substitute for establishing private property rights. If a country chooses to orbit a satellite despite the tax, then it is apparently worth more to the country orbiting the satellite than it is worth to other countries facing the increased problem of congestion.

A tax on congestion would appear to result in an optimal number of satellites being placed in orbit at any point in time. But there is a *flaw in this argument*. One is tempted to conclude that the proper place to impose the tax is on the country orbiting the satellite. But the country "causing" the congestion is not always the proper place to impose the tax. The very existence of other countries interested in occupying the orbital slots can also be viewed as a cause of the congestion problem. The obvious cause of the congestion problem is not always the best place to impose the tax burden.

When the costs of making deals between countries are low and trade is possible, it does not matter where the tax burden is placed. Adam Smith's generalization guarantees that an efficient outcome will still prevail. But if the costs of making deals are high, then Coase's theorem that it *does* matter where the liability is imposed supersedes Smith's generalization.¹⁰ Placing the tax burden on the country orbiting the satellite may lead to an inefficient outcome. Consider, for example, that total world income would be higher if it were cheaper for the countries facing the congestion to find other means of communication than it would be for the country orbiting the satellite to pay the tax. It would be inefficient to impose a tax on the country orbiting the satellite when total world income is maximized by other countries using alternative methods of communication. Regardless of where a congestion tax is imposed, it is still a substitute for private property, and if transactions costs are low, a system of congestion taxation can lead to an efficient and equitable outcome.

⁹It is difficult to imagine how this amount would be determined. For this reason, many economists believe that the imposition of taxes to deal with the externalities caused by congestion inevitably leads away from the social optimum. No public authority, no matter how well intentioned, can compete with a market system in evaluating the effects of externalities (Davis and Whinston 1962). Negative externalities due to congestion are dealt with, in a free market, by the existing owners paying potential owners of orbital slots not to orbit geosynchronous satellites.

¹⁰In fact, the property rights literature emphasizes the idea that externalities are associated with transactions costs, including the costs of exchanging and enforcing property rights (Demsetz 1964, 1966).

Conclusion

The market system applies to scarce resources in outer space as well as to resources on earth. Scarce orbital slots for geosynchronous satellites can be efficiently allocated if property rights are assigned and exchange is permitted. The assignment of property rights, if abided by and done in a spirit of cooperation, need not be feared. Clearly defined property rights underlie well-functioning markets, which are socially beneficial.

This paper has dealt with the issues of why the establishment of property rights to geosynchronous orbital slots is inevitable and how these property rights can be created. The focus has been on economic efficiency. The analysis of alternative allocation schemes suggests that competitive markets can be applied usefully to the problem of allocating scarce orbital slots for geosynchronous satellites.

Clearly defined and enforced property rights provide sufficient incentives to preserve scarce resources. Scarcity in the absence of ownership leads to congestion, inefficiency, and a misuse of resources. Failure to assign property rights leads to socially undesirable outcomes. Policy issues that are concerned with equity, as distinct from efficiency, involve interpersonal comparisons of utility and social welfare judgments on the part of bureaucratic authorities. Further research will be required to investigate the equity implications of establishing property rights in outer space, given the current international distribution of wealth and technology.

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