Scarcity of Lunar Resources

Policy Brief

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Table of Contents

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Scarcity, what's the problem?

With increasing space resource utilisation, the term "scarcity" will become an important concept for policymakers when contemplating the future governance and economic development on the Moon and other outer space environments. Scarcity occurs when the demand for something is greater than the availability of it. That good or service can be anything, from physical space to orbits around the moon or the supply of fresh water. This relationship is critical to how resources are valued, allocated, and managed. Figuring out how to efficiently and fairly allocate scarce resources is the fundamental goal of virtually all economic theory (Hotelling, 1931), and is the basis for sustained life on and off Earth.

As on Earth, how we balance the trade offs between satisfying current demand and compromising future supply of resources has direct socioeconomic and environmental impacts. The extraction of fossil fuels, for example, has helped foster periods of enormous economic growth and technological advancement. But, its use has also contributed to climate change and severe natural disasters, negatively impacted human health, been a source of military conflict, and damaged countless ecosystems. Suffice to say, all the costs and benefits associated with the acquisition and consumption of resources must be internalized to sustainably manage environments on Earth and in outer space.

The traditional way to balance the trade offs and externalities of resource utilization involves economic strategies, or resource management systems, that seek to: i) calculate the costs associated with consuming and supplying resources, ensuring they do not exceed the benefits of doing so (Krautkraemer, 1998); ii) decide how much of a resource should be consumed in the present or preserved for the future; and iii) distribute the costs and benefits of consuming these goods. Where policymakers often utilize resource management systems to maintain balance in their own countries, there is currently no such system in place on the Moon - or any other outer space environment for that matter. This poses a problem for all actors seeking to operate in space as the Moon, and its resources, will play a vital role in future deep space exploration and the development of space economies (NASA, 2020). Without logical mechanisms to effectively manage lunar resources (i.e. water, physical space, valuable minerals, orbits) the Moon may become vulnerable to the many problems that can arise from resource scarcity, and actors operating in space will be left to fend for themselves.

There are several outcomes to be concerned about here: the over-extraction and ultimate depletion of finite resources, coupled with irreversible and unmitigated environmental damage to lunar ecosystems that compromise the safety and

sustainability of lunar activities (*the sustainability problem*); the benefits of lunar resources becoming inequitably concentrated amongst actors, combined with the adverse moral and economic impacts this condition promotes (*the first-come-first-served problem*); and finally, as resources become more scarce, it can create the necessary conditions for conflict to arise between actors vying for control over the limited supply or those looking to capitalize, financially or politically, from the higher prices scarcity induces (*the conflict problem*). While this is not a complete list of all the potential drawbacks related improperly managing lunar resources, these are certainly priority issues for policymakers to focus on.

Why should we care?

There are countless historical examples on Earth of what happens when we care for our environmental riches incompetently. Although some high-level agreements and treaties have been struck to address some of these issues, like the recent 30x30 Leaders Pledge to protect oceans and land from biodiversity loss, the future of many natural goods and environments – and the organisms that depend on them – are still in jeopardy (Leaders Pledge 4 Nature, 2022). The fact remains that the scarcity of resources can lead to unfathomable and uncontrollable consequences for those who rely on them or the environments from which they come. Unique to outer space environments is that as all actors have equal access to the same resources, all of humanity will share in the burden of their mismanagement (UNOOSA, 2018). Below, I will outline a few of the problems associated with resource scarcity on the Moon and why it is essential for policymakers to be looking for solutions to them now.

The Sustainability Problem

Perhaps the most obvious concern is the potential for valuable, yet finite resources to become unavailable in the future. Although space resources are often viewed in the literature as “limitless”, in theory, any resource can become scarce depending on the supply available and the level of demand for it (Koundouri, 2000; Investopedia, 2021). There are many factors that can affect scarcity: accessibility, technological advancement, economic policy, laws and regulations, and cultural traditions, to name a few. Ironically, if effective strategies to control supply and demand are put in place *before* resources start becoming exploited, the present utilization of resources should be of minimal concern to the future. However, policymakers are often slow to act in this regard, especially when it comes to common pool goods that all humanity has equal claim to or environments beyond national jurisdictions. Strategies are commonly implemented only *after* resources are heavily diminished, rather than designed to proactively prevent resources from becoming scarce in the first place. This pattern is evident, for example, in the 97.4% global decline of Bluefin Tuna

populations, which are typically caught in international waters, are a staple in sushi restaurants all over the world, and have only recently started being protected (Nickson, 2016). On the Moon, we will need to be cognizant and alert to how precious the resources are, especially since they will be essential for future missions in space and potential lunar industries. Looking further ahead, lunar resources must also be protected from overexploitation in order to fairly share the benefits with all nations and future generations of humanity.

Linked with the depletion of resources is the toll that extraction and utilization take on the environment. Many economists studying scarcity and sustainability will note, in order for operations to be efficient and sustainable, the costs of extracting and utilizing resources must not outweigh the benefits they provide; however, the environmental and social costs associated with these processes are routinely undervalued and undercompensated to justify further extraction (Krautkraemer, 2005). The effects of climate change on Earth are a perfect example of what happens when these costs are not adequately considered. If this trend occurs on the Moon, the limited number of desirable lunar environments will quickly degrade, threatening the viability of future lunar communities and deep space missions that require a human lunar presence. As scholars like Gupta (2016) have pointed out, the deterioration of outer space domains poses a serious threat to future generations and uses of space. Environmental damage in space, which includes the depletion of scarce resources, can be a safety hazard to personnel, costly to mitigate, and have unintended consequences that are difficult to predict (and risky to investors). For example, the propellant used to navigate to water ice locations on the Moon could alter the lunar environment and contaminate the very water source a mission was sent to collect (David, 2020). As Planetary Exploration Group scientist Parvathy Prem concludes:

> "When we visit [the Moon], we will inevitably alter it, temporarily or permanently. I would say that understanding and planning for the impact of spacecraft systems on the lunar environment is critical to carrying out meaningful and responsible science,"(David, 2020).

This is to say that if humanity is to sustainably explore and utilize the Moon and other celestial bodies, we must manage our environmental impacts. This involves preventing environmental contamination, but also incorporating strategies to protect the valuable resources that reside in space for future generations.

The First Come, First Served Problem

The first come, first served (FCFS) problem arises when there are no rules in place to regulate who gets access to a specific common resource, when individuals can access it, or how much of that resource can be acquired or utilized at any given time

(Schrijve, 2016). Effectively, this allows those with the ability to access a resource first to claim as much of it as they deem fit (UNOOSA, 2017). Although this can be advantageous for those individuals with the ability to claim resources, it can have damaging effects on the resource system and unfairly prevent others from acquiring their equitable share. These conditions incentivize individuals to neglect the well-being of society in the pursuit of their own self interest, leading to the overconsumption and depletion of common lunar resources, to the detriment of *all* actors. Proceeding with the utilisation of resources on the Moon without any new rules or coordination systems will re-create this problem; it will provide an asymmetrical advantage to those most capable space actors with the ability to access and utilize space resources first at the expense of others - specifically those currently lacking the capability to conduct space resource utilization (SRU) activities and future actors who may want to use these resources for their own development or space missions.

While it may be beneficial to reward or incentivize exploration into new frontiers, such conditions may raise questions about Article I of the Outer Space Treaty, which states that space activities, including SRU, are to be "carried out for the benefit and in the interest of all countries" (UNOOSA, 1966). Providing advantage to the already privileged inherently carries with it certain moral implications that will be problematic for the long-term, sustainable development of lunar-based economies. Furthermore, the current free-for-all approach also adds unnecessary risk and uncertainty to lunar operations. For example, nations may become uncertain if they will be able to access space resources; investors could question if they will see a return on their investment; and politicians could fear that SRU activities will lead to conflict or political turmoil (Weinzierl, 2018; Jackson, Kliesen, & Owyang, 2018). Unfortunately, too much risk and uncertainty is detrimental to the long-term development of space economies and unmanaged utilization of space resources will likely result in their rapid depletion. In order to prevent both of these outcomes, policymakers will need to work together to create new regulatory circumstances that resolves the FCFS problem and provides the means for all actors to access, utilize and conserve space resources well into the future.

The Conflict Problem

Another concerning problem associated with resource scarcity is its tendency to increase tension between individuals looking to use or control resources, which ultimately lead to and prolong conflict. There has been much research conducted on Earth about the link between resource scarcity and the onset of conflict. In a simple explanation, resources are a source of wealth, power, opportunity, and cultural significance, among other things. And as one might imagine, there can be fierce competition to control important and lucrative resources. This fight for control can

manifest in political, economic and even armed conflict between those actors vying for control (Maxwell & Reuveny, 2000). The potential for conflict escalates as the supply of desired resources declines, the price or demand for them increases, or there are weak laws and institutions in place to protect them from exploitation (Collier & Hoeffler 2004; Humphreys, 2005). Although the linkage between resource scarcity and conflict has mostly been studied in a terrestrial context, the same basic theories likely apply in outer space environments.

The lesson here is that as resources become scarce, major security issues arise – which could escalate to the point where protecting acquired resources by physical force may be required (Starling et al., 2021). Beyond this, conflict in space (physical or not) can negatively impact space exploration and the actors involved in several ways: i) it threatens the safety of personnel and space assets; ii) increases the risk of space exploration, and therefore the costs associated with it; iii) can slow the development of and investment in new space economies; iv) jeopardizes space capabilities that the global society increasingly relies on; and v) it increases the potential for conflict to extend back to Earth (Secure World Foundation, 2021). Put simply, conflict in space is bad for everyone in so many ways. However, space resource utilisation managed effectively could curb security risks and prevent future tension, while maintaining the conditions required to secure the socioeconomic and scientific benefits outer space provides.

What can we do about it?

While the acquisition and use of lunar resources is still in its infancy, with mostly unknowable levels of supply and demand at this point, now is the time for policymakers to be thinking ahead about scarcity and effective management. To begin this thought process, let's explore three recommendations policymakers could take as steps towards an effective resource management system.

Firstly, there needs to be formal recognition by the international community that all lunar resources are scarce, at least to some degree, and steps must be taken now to prevent their depletion in the future. This aspect is important as it commits stakeholders to recognize that a problem exists, and they owe it to their respective constituents to mitigate it. This gesture could come in the form of an international agreement, or amendments to the Outer Space Treaty, for example. However, a more subtle approach, such as the inclusion of an agenda item in a working group, will likely be a more politically feasible first step for policymakers. Leaders could push for such an inclusion in the mandate of the Space Resources Working Group of the Committee on the Peaceful Uses of Outer Space (COPUOS), as this body has been relegated to studying the various challenges and benefits associated with the exploration, exploitation and utilization of space resources (COPUOS, 2021). The

inclusion in the working group's mandate could permit an investigation into potential resource management strategies for lunar resources, methods for calculating scarcity, and the possible benefits of ownership rights over space resources. Without formally recognizing that the abundance of lunar resources are worth monitoring, it is unlikely that initiatives to safeguard them will be implemented.

Secondly, world leaders and other space actors must come together to not only agree that the scarcity of lunar resources is something worth monitoring, but also develop basic methods for identifying and calculating scarcity. The latter will likely prove the more difficult task. As Cleveland and Stern (1998) make clear, there is no one-size-fits-all approach to measuring scarcity that captures all the possible factors influencing the abundance of resources. In other words, different resources have unique characteristics and factors acting upon them that will require tailored econometric methods for estimating their level of scarcity. Experts are also divided as to which methods to calculate scarcity are the most effective, making the prospects of a standardized method for calculating scarcity unlikely. However, a more general approach to classifying resource scarcity could be adopted to prioritize which resources must be conserved first. One possibility is creating a type of "score card" of indicators affecting the scarcity of a particular resource, such as the estimated supply of the resource or its renewability, and generating a "scarcity score" that designates which resources are most vulnerable. This could be done on a case-by-case basis for all forms of lunar resources and may be expanded to include more specific indicators as our understanding of scarcity evolves. Without a common understanding and methods to estimate scarcity, policymakers will be hard pressed to develop resource management strategies that can effectively control overexploitation.

Finally, policymakers need to consider adopting a system of ownership rights over lunar resources. Such a system will be integral to counteract forces influencing scarcity and reduce the likelihood of the problems outlined in the previous sections of this paper. Ownership and property rights are essential to the proper functioning of market economies that buy and sell resources, while providing legal coverage and protection for those that have acquired them (Ostrom, 2000). As Kostenko suggests, "the ability to develop the right of ownership of private enterprises, companies, research centers is extremely important for the economic development of the space industry" (Kostenko, 2020). Conveniently, ownership rights also make it easier for governments to regulate, legislate and conserve specific resources through market mechanisms that alter their supply and demand.

On the surface it seems counter-intuitive to allow the legal ownership of resources to prevent resource scarcity. On one hand, a new legal right to own space resources could incentivize extraction, thus reducing the abundance of certain lunar resources.

On the other hand, having the ability to track, regulate and sanction the sale or use of resources can be a useful tool in conserving resources, if managed properly. This is not to suggest a free-market approach, but rather that a well regulated market that closely monitors the supply and demand of vulnerable resources. With the alternative, which is no specific laws for or against the ownership of space resources, actors are free to utilize as much of any resource they have access to. This is problematic from a scarcity standpoint, but also from a moral perspective. In this scenario, the biggest, wealthiest actors with the ability to reach resources first have a considerable advantage over smaller players or nations without advanced spacefaring capabilities. In theory, these bigger actors could utilize all the available resources before others even have the chance to access them. The broader point here is that a fair, internationally regulated market for lunar resources that recognizes ownership rights over resources will be key to developing resource management strategies that prevent resource scarcity. While some countries, like the United States and Luxembourg, have recently developed their own national legislation permitting actors the right to own resources acquired in space, there currently remains no internationally recognized system of ownership laws over space resources (Jakhu & Pelton, 2017). If the international community wants to control scarcity on the Moon in a way that does not stifle the development of space economies, it has little choice but to adopt some mechanism that permits control over resources.

Conclusion

If policymakers are serious about pursuing the sustainable development, exploration and utilization of outer space they must start considering the central role scarcity plays. Managing a healthy relationship with scarce resources is a prerequisite to flourishing space economies. Alternatively, the rapid depletion and mismanagement of resources on the Moon and beyond can have several undesirable impacts. Environmental degradation, resource depletion, sluggish economic development and armed conflict were cited here. But these are just the tip of the iceberg. These issues can be mitigated if action is taken to embrace strong management dynamics of scarce resources.

Cross-sectional collaboration to adopt a resource management framework addressing scarcity in a way that fairly balances the interests of all stakeholders - small and large, rich and poor, present and future - would be a fantastic policy base on which to build a space economy. However there is a time window in which we must collectively work towards this; that is *before* SRU becomes commonplace and these problems are allowed to take root. Coming to broad agreement that space resources need management, a system of ownership rights and methods for monitoring usage are great starting points. That said, more tangible policies,

regulations and laws will be required if we are to preserve lunar environments and create a sustainable space economy that benefits all of humanity for many generations to come.

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