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The organizational ecology of the global space industry

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ABSTRACT

The global space industry is booming. While governmental agencies used to dominate outer space activities, private space organizations (PSOs) now launch rockets, operate strategic satellites, and even take tourists on space expeditions. How can we explain this emergence of PSOs? Building on organizational ecology theory and drawing on a novel dataset of 1751 space organizations and 52 semi-structured interviews, this paper finds that mutualistic relations between governmental space agencies and PSOs have been instrumental in the rise of PSOs. This emphasis on mutualism challenges the prevailing belief that a few visionary private entrepreneurs create the space industry from the ground up. It also refutes the notion that PSOs simply out-compete a stagnant public sector. PSOs have not superseded governmental space agencies; they are nurtured by and developed with them. This paper is one of the first to explain how private actors can emerge in a field historically dominated by governmental actors. In so doing, it contributes to studies on public-private interactions by showing how mutualism can structure a nascent industry. It also opens up new avenues for research on the political economy of outer space by making available a rich dataset of space actors.

KEYWORDS

Political economy of outer space; space industry; regime complexity; organizational ecology; mutualism; symbiosis

Introduction

In July 2021, Blue Origin and Virgin Galactic launched the first two commercial flights into space with passengers on board. The development of space tourism is only the most recent example of the 'new space' era, which is marked by greater private sector involvement (Cross & Pekkanen, 2023; Denis et al., 2020; Orlova et al., 2020, p. 1; Paikowsky, 2017). In addition to taking tourists to outer space, private space organizations (PSOs) now launch rockets, operate satellites, track

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space objects, design and manufacture spacecrafts, offer remote sensing services, regulate space activities, conduct space exploration missions, bring astronauts to the space station and land equipment on the surface of the moon. The rise of PSOs in a field that used to be dominated by a handful of governmental space organizations (GSOs) has far-reaching implications, including for global telecommunications, transportation systems, fundamental science, and warfare (Golkar & Salado, 2021; OECD, 2019). The Ukrainian military's reliance on Starlink satellites to access the internet exemplifies the increasing value of private space technologies in interstate conflicts.

How can we explain this emergence of PSOs? Some space experts refer to the capacity of a few individual entrepreneurs to disrupt the status quo thanks to their vision, innovativeness, and investments (Quintana, 2017). Other experts link the rise of PSOs to the decline in funding provided to GSOs (Weinzierl, 2018). Yet others emphasize the role of new technologies in reducing the costs of doing space activities (Sweeting, 2018). As of now, this question has not been thoroughly theorized and empirically investigated.

More generally, we ask, beyond the case of PSOs, how do private actors emerge in a field dominated by governmental entities? Several sectors, including aviation, nuclear production, and the Internet were once the preserve of public organizations but eventually became open to the private sector (Abbate, 1999; Clarke, 1985; Van der Linden, 2002). Recent scholarship in international political economy (IPE) highlights that even traditional public governance activities, such as regulating behaviors, monitoring compliance, and sanctioning offenders, are increasingly conducted by private actors (Abbott & Faude, 2022; Avant et al., 2010; Cutler, 2010; Eilstrup-Sangiovanni & Sharman, 2022; Green, 2013). However, these studies often assume the existence of private actors capable of assuming new roles without delving into the question of how a nascent industry can emerge in a field historically monopolized by government actors.

This paper builds on organizational ecology theory to explain the emergence of a population of private actors in outer space research, technology, and industry. Organizational ecology is a well-established theoretical tradition in organizational studies. Following Abbott et al. (2016), an increasing number of IPE scholars draw from this tradition to explain variations in the population size of organizations (Bush & Hadden, 2019; Downie, 2022; Eilstrup-Sangiovanni, 2020, 2021; Lake, 2021; Morin, 2020).

Informed by organizational ecology theory, we argue that a mature population of GSOs strategically facilitated the emergence of a new population of PSOs to capitalize on the resources they provide. We analyze an original dataset of 1751 space organizations and 52 semi-structured interviews and find strong descriptive evidence supporting our argument.

Our findings contrast with popular narratives of PSOs emerging under the impetus of a few billionaire entrepreneurs. It also challenges the notion that agile PSOs are outcompeting a stagnant public sector. Rather than being locked in a zero-sum game, where the growth of one negatively affects the other, we show that PSOs and GSOs have grown in a mutualistic manner. We expect that the emergence of a private sector in a field dominated by public organizations is particularly likely to be the result of such mutualistic strategies when barriers to entry are high.

Our case study also adds to the existing scholarship on global space politics, which has primarily focused on GSOs (Cross, 2021; Early, 2014) and power rivalry (Johnson-Freese, 2016; Moltz, 2011). Our original dataset of space organizations, made publicly available with the publication of this study,[1] provides the first comprehensive map of the organizational ecosystem in outer space. It offers empirical grounds for researchers interested in investigating space politics and/or economics.

The remainder of this paper is divided into five sections. First, we introduce our theoretical argument based on organizational ecology, detailing how we expect mutualistic relationships to favor the emergence of new organizational forms facing high entry costs. Second, we present our data and methods, including the construction of our original dataset of space organizations. Third, we investigate this dataset and provide evidence supporting our organizational ecology explanation. Fourth, we rely on 52 semi-structured interviews conducted with executives from 20 countries to detail how mutualistic relationships among public and private space organizations shaped the emergence of the latter and the sustained growth of the former over time. Fifth, we contrast our findings with existing narratives in public debates about the emergence of the new space era.

Organizational ecology theory

Organizational ecology focuses on populations of organizations as its unit of analysis (Carroll, 1984; Hannan and Freeman, 1977). A population of organizations is a group of organizations sharing the same organizational form. In turn, this form shapes the population's 'fundamental niche', i.e. a set of resources that all organizations from a given population can *potentially* consume to survive (Carroll, 1984; Hannan & Freeman, 1977).[2] It is common in the organizational ecology literature to compare a population of public organizations with a population of private organizations. While public and private organizations may consume some similar resources, such as employees, data, media exposure, and technologies, they have distinct organizational characteristics that make certain resources vital for one population but not the other. Private organizations require clients to survive, whereas public organizations depend on political support. Although their niches overlap to some extent, organizational ecology recognizes that public and private organizations belong to different populations.

The macroscopic level of analysis favored by organizational ecology makes it suitable for theorizing the emergence of new organizational forms. This section first presents the two core processes of organizational ecology, namely, 'legitimization' and 'competition'. It then focuses on the particular question of 'speciation' at the core of this article. Next, it distinguishes commensalism from symbiosis as two types of mutualism. Finally, it provides an original framework that explains the emergence of new organizational forms when there are high barriers to entry.

Legitimacy and competition

A growing body of literature in international studies applies insights from organizational ecology to explain variations in populations' *growth rate* (e.g. Abbott et al., 2016; Gehring & Faude, 2014). According to the tenets of organizational ecology

(Carroll, 1984; Hannan & Freeman, 1977), a population's growth rate is related to its density. Two main processes connect density to growth: legitimization and competition. Take legitimization first. When a population has a low density, indicating the availability of ample resources for existing organizations in a particular field, the addition of one new organization helps its organizational form gain recognition and increases the population's legitimacy. Greater legitimacy, in turn, favors the population's growth by allowing its organizations to gain access to new resources. For example, the introduction of Uber drivers in a new market makes their service better known to the local population, which increases the number of consumers and ultimately attracts more drivers. However, at a certain point, when an organizational form has acquired a taken-for-granted status, the addition of an organization does not significantly increase its population's legitimacy. Therefore, as density increases, the effect of legitimization on a population's growth reduces.

Competition becomes the main process at play when a population reaches a high level of density and fewer resources remain available to existing organizations. In a dense environment, a marginal increase in the number of organizations intensifies competition and limits the population's growth. The entry of a new Uber driver in a saturated market does little to attract new consumers, but exacerbates competition and makes the business less attractive to new drivers. In short, legitimacy increases with density at a decreasing rate, while competition increases with density at an increasing rate. When these two processes are combined, density-based explanations expect the growth rate of a given population to follow an inverted U-shaped curve, as Figure 1 illustrates (Hannan & Freeman, 1977).

Following the introduction of these organizational ecology ideas into international studies, multiple contributions documented the existence of this inverted U-shaped curve. Studies show that legitimization and competition processes impact the growth rate of intergovernmental organizations (Eilstrup-Sangiovanni, 2020; Shanks et al., 1996), including in the fields of climate change (Abbott et al., 2016) and energy (Downie, 2022). Other studies suggest that these processes partly explain the growth rate of transnational organizations, including international NGOs (Bush & Hadden, 2019), technical assistance providers (Morin, 2020), and international accounting organizations (Lake, 2021).

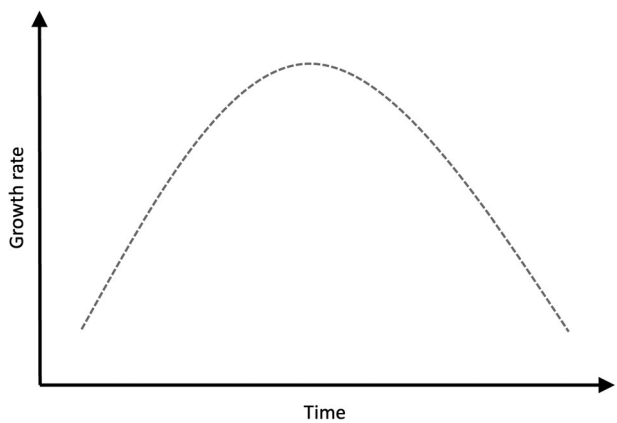

Figure 1. Density-based expectation of a population's growth rate.

The puzzle of speciation

This paper differs from most studies in organizational ecology as it aims to explain the *emergence* of a new population, which is also known as the 'puzzle of speciation' (Padgett & Powell, 2012). It is worth noting that speciation does not refer to the creation of a single organization that consumes a different set of resources since a single organization does not constitute a new population. Population emergence occurs when its constituent organizations are sufficiently similar to share a common form and a common niche that are distinct from other existing populations (McKelvey, 1980). The process of population emergence generally spans over a long period of time.

Resource availability alone is not sufficient to trigger the emergence of a new population. New populations typically have some form of lineage with pre-existing ones. Therefore, studying population emergence requires a macroscopic level of analysis that can embrace multiple populations at once. Organizational ecologists refer to this higher level of analysis as a 'community', which can be defined as a set of two or more interacting populations in a given field (Hannan and Freeman, 1989, p. 14). Lake (2021) offers one of the first community-level analyses in international studies by examining the relationship between the density of governmental organizations, intergovernmental organizations, and private organizations.

Density-based explanations, which commonly explain the evolution of a population's growth rate, can also shed light on the emergence of a new population at the community level. A high degree of competition within a population incentivizes organizations to specialize in a limited area of their shared niche. Over time, these specialized organizations cultivate and expand their resource space until it becomes a distinct niche that is inaccessible to more generalist organizations (Freeman & Audia, 2006). Hence, new populations often stem from mature populations with a high degree of competition. Once established, the new population partly competes with the older one, further contributing to the slowdown in its growth rate and potentially making it negative. Therefore, density-based explanations suggest that populations grow sequentially within a community, as illustrated in Figure 2.

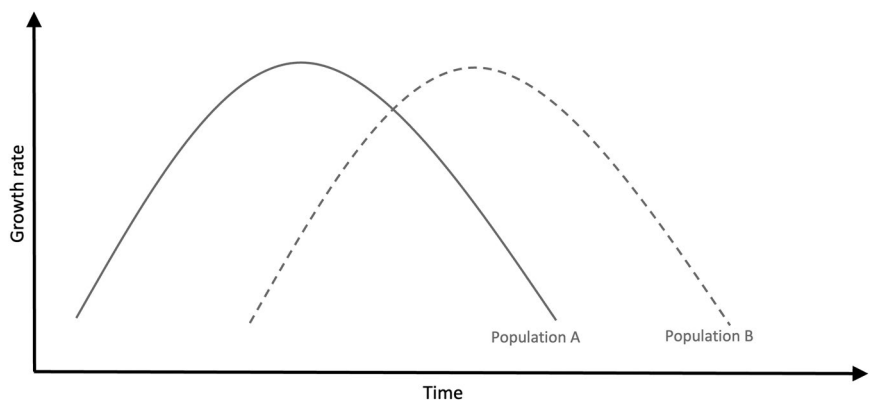

Figure 2. Density-based expectation for the sequential emergence of a new population.

Two types of mutualism

Focusing solely on competition and legitimization leaves little room for agency. In reality, organizations do not sit idly by, waiting for resources to materialize. They actively seek new resources and, in doing so, interact with each other in various ways. While organizational ecology is primarily a structural theory (Abbott et al., 2016; Voeten, 2019), paying attention to organizations' strategies in a competitive environment is a way to balance the dual forces of agency and structure.

One organizational strategy is to form 'mutualistic relations' within and across populations. In organizational ecology parlance, mutualism describes interactions that benefit both partners (Barnett & Carroll, 1987, p. 400). This paper distinguishes between two types of mutualistic relationships: symbiosis and commensalism (Freeman & Audia, 2006, p. 149; Hawley, 1950).[3] Symbiotic relations involve actors with different resource consumption patterns. Organizations in symbiosis take advantage of their complementarity to provide each other resources or legitimacy (Baum & Singh, 1994). For example, studies have found symbiotic relations between local microbreweries and national brewers (Boeker, 1991), and between radical and moderate civil rights organizations (Haines, 1984). In international studies, Bownas (2017) used the organizational ecology framework to reveal symbiotic relations between transnational NGOs that are anti-GMOs, international donor organizations, and global retailers. Similarly, Green and Hadden (2021) found that a population of environmental NGOs and a population of intergovernmental organizations enhance each other's legitimacy, which boosts their synergistic growth. Through their symbiotic interactions, two populations of organizations can also accentuate their division of labor, supporting in the process the differentiation of their activities and respective niches (Henning, 2023; Henning & Pratt, 2023).

In contrast, commensalism is a form of mutualistic relation based on similarities between organizations (Hawley, 1950, p. 39). Since organizations that belong to the same population share a similar form and niche, commensalism mainly occurs within populations. Although sharing the same niche or set of resources may lead organizations to compete with each other (Johnson, 2016), organizations from the same population have a shared objective: to increase their organizational form's legitimacy and expand their joint niche. Rival firms, for example, can institutionalize a commensal relationship by setting up an industrial lobby group to defend their interests and promote a positive image of their industry. In international relations, Downie finds that similar intergovernmental organizations cooperate around Sustainable Development Goals to increase their legitimacy before their member states (2022, p. 379).

Most studies that have examined mutualism in organizational ecology focus on the simultaneous growth of two populations, as illustrated in Figure 3. Green and Hadden, for example, argue that mutualism 'can explain simultaneous growth of two different populations' (2021, p. 1794). This simultaneity derives from synergies and mutual dependence. From their perspective, 'a pattern of sequential growth […] would be broadly indicative of density dependence, while simultaneous growth would be more indicative of mutualism' (2021, p. 1799).

Our perspective differs from that of Green and Hadden (2021, p. 1796). Rather than contrasting competition-based and mutualism-based explanations, we agree with Barnett and Carroll (1987) that competition and mutualism can coexist both

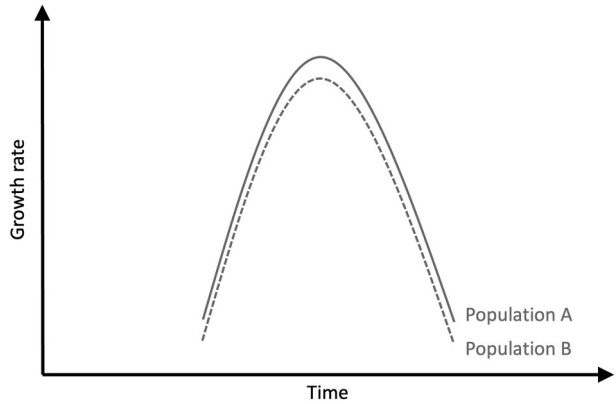

Figure 3. Mutualism-based expectations of two populations' synergistic growth.

within and among populations. Two organizations within the same population can collaborate to acquire certain resources while also competing for others (Boeker, 1991). This duality can also exist in the relationship between two populations operating within the same community. More fundamentally, mutualism is a strategic response to an intensely competitive environment. Therefore, we argue that mutualism is not limited to the simultaneous growth of two populations. As we explain below, it can also be associated with sequential growth and the emergence of a new organizational form while the growth rate of an older population plateau.

Bringing together legitimation, competition, mutualism, and speciation

This paper brings together the concepts of legitimation, competition, and mutualism to explain the sequential emergence of new organizational forms. More specifically, we argue that the mutualistic support of a highly competitive population can interact with self-reinforcing legitimacy to give rise to speciation. When a mature population is dense, some organizations may react to this competitive pressure by trying to expand their niche. This strategy generates demand for resources, which a new population can potentially supply. If the supply of new resources is inexistent or insufficient, organizations from the mature population might actively favor the creation of another population. This is particularly likely when barriers to entry are high and new organizations do not spontaneously emerge to respond to this demand. In this situation, large and general organizations facing intense competition in their population are particularly likely to aim to have 'organizational progeny' in a new and emerging population (Johnson, 2014). They have the capacity (resources), as well as the interest (being more competitive) to create and cultivate a new population that will provide them with even more resources (Romanelli, 1991). From the outset, the new population's organizational form will be designed to develop symbiotic relations with this well-established population.[4] In turn, symbiosis with a well-established population gives the emerging population additional resources and cross-population legitimization (Baum & Singh, 1994; Ruef, 2000). For example, Eckl and Hanrieder (2023) have shown that international

organizations with precarious funding support the emergence of a population of consultants to provide them with new and more flexible resources.

Meanwhile, commensalism within the emerging population can favor its growth by increasing its legitimacy. When a population is still at an early stage of development and its new organizational form does not yet have a taken-for-granted status, commensalism can enhance its legitimacy and increase its growth rate. At this early stage, intra-population competition remains moderate and does not pose obstacles to commensalism. Commensalism also contributes to establishing a degree of internal isomorphism, which is necessary to stabilize an emerging organizational form.

Following this explanation, we would expect the old and new populations' growth rate to follow a trend that combines elements from density-based and synergistic explanations, as Figure 4 illustrates. First, we expect the initial growth of population A to be similar to that depicted by the classic inverted U-shaped curve. When population A becomes dense, competition overtakes legitimacy as the dominant process, and we expect its growth rate to gradually slow down. In turn, intense competition pushes organizations to actively support the creation of a new population. Symbiotic and commensal relations can support population B's early growth. Population A can actively help population B to access new resources and organizations, and population B can cooperate to increase their legitimacy and expand their resource pool. As a result, population B's initial growth rate should be greater than if it were driven solely by increasing population density. Moreover, we expect that symbiotic relations with population B will mitigate population A's reduced growth rate and flatten its curve.

To clarify, we do not suggest that mutualism cannot lead to the simultaneous and synergistic growth of two populations, as conceptualized, for example, by Green and Hadden (2021). However, we contend that this is not always the case. In certain scenarios, mutualistic relations can favor the sequential emergence of a new population while the growth of the older population stagnates. We expect mutualism to be more commonly associated with synergistic growth when entry costs are low, as for environmental NGOs examined by Green and Hadden (2021). Under conditions of low entry costs, the growth of one population creates a demand for resources that another population can rapidly and easily fulfill. However,

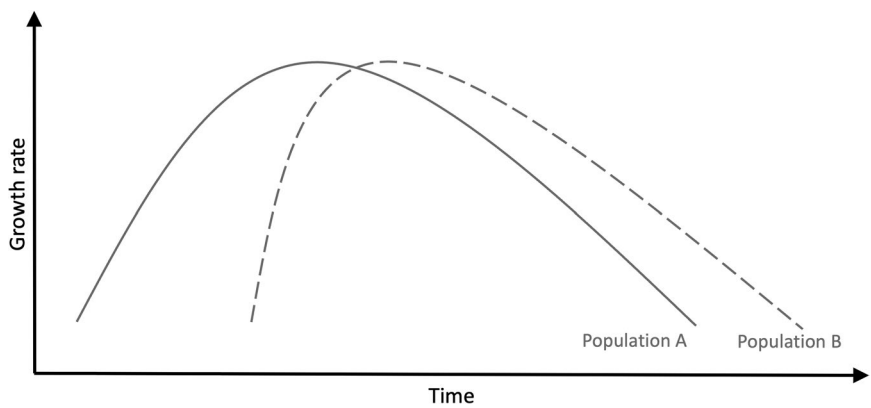

Figure 4. An integrated expectation relative to the emergence and growth rate of populations.

in situations of high entry costs, we expect that the growth of the first population will not immediately prompt the emergence of a new population, as it requires greater investment and risk-taking. It is only when the competition reaches high levels that it becomes more advantageous for the initial population to actively support the emergence of a new population that can either help it access new resources or more efficiently use those at its disposal. High entry costs can also lead to commensalism within this second population as its organizations both need as much assistance as possible to grow their activities and are better insulated from intense intra-population competition in the short term. Hereafter, we probe our argument by looking at the emergence of private companies in space activities, a field characterized by high entry costs.

Data and methods

One reason few international studies have looked at the emergence of new populations of organizations is the lack of longitudinal data on the birth and death of organizations. It is a problem that frequently occurs in organizational ecology (Amburgey & Rao, 1996, p. 1270), especially with regard to transnational populations (Ries, 2017, p. 164). Most studies in organizational ecology look at the rise and fall of domestic industries since organizational demographic data is more frequently available at the domestic than at the global level.

Until now, no database has tracked the proliferation of space organizations over time and around the world. Early (2014) studied the diffusion of space capabilities across nations since 1950 but did not document the emergence of PSOs. Some consulting firms track the revenue of publicly-traded PSOs, investment in the space sector, and the number of orbital launches (Bryce Space and Technology, 2021; ESPI, 2019; Euroconsult, 2022; NSR, 2022). However, their reports offer limited coverage in terms of time periods, world regions, or space sectors. As a result, many space experts make generalizations about the entire space industry based on the experience of a few prominent businesses. They link the emergence of the space industry to well-known companies like SpaceX, thereby assuming that the 'direct participation of private companies in the space sector started in the early 2000s' (Orlova et al., 2020, p. 101374). With this study, we introduce a novel database on space organizations.

We define a 'space organization' as an organization that designs, owns, launches, operates, tracks, monitors, removes, or regulates objects in space or has concrete plans to do so within the next three years. This definition includes organizations as diverse as the People's Liberation Army, AT&T, Ohio State University, the Vietnamese Posts and Telecommunications Group, and the International Standards Organization. However, it excludes other space actors, such as NGOs that merely undertake educational activities, equipment manufacturers, and media specialized in space news.[5] We have found 1751 organizations that fit this definition based on extensive research in industry reports and public documentation. For each one, we collected information about their year of creation, year of termination (if applicable), location of headquarters, size, sector, activities, and the year of their first satellite launch.

Our new dataset reveals that the geographical diversity of the space sector is more significant than often assumed, judging from the amount of media coverage

given to a handful of companies. While the US has the most space organizations, 30% of space organizations in our dataset have their headquarters in low- or middle-income countries. Our dataset also shows that the size of these space organizations varies significantly. Besides large companies like SpaceX, which has thousands of employees and a revenue exceeding $1 billion, our dataset includes hundreds of organizations with fewer than 50 employees and an annual budget of <$10 million.[6] Figure 5 presents the distribution of space organizations by their budget in constant US dollars for 2015, with the sum of organizations per budget category indicated above each column. It excludes organizations for which we could not find information on their budget.

Moreover, our original dataset allows us to observe changes in the activities performed by space organizations over time. Based on previous space research, we identified seven types of activities performed by space organizations, which range from (1) designing, (2) owning, (3) launching, (4) operating, (5) tracking, and (6) regulating space objects. A category for 'other' space activities includes the few that could not fall into any of these six main types of space activities. Figure 6 shows the evolution of the share of activities performed by new organizations every year from 1960 to 2019. It represents the ratio of new organizations created each year performing one type of activity over the total number of new organizations created in the same year. Some organizations may perform multiple activities, and the sum of the share is thus >100. According to our dataset, 72% of all GSOs and PSOs effectively perform two or more space activities, and 41% three or more. Each line represents the LOESS regression that best fits the yearly share of organizations conducting a specific type of activity, illustrating the overall trend in activities performed by space organizations over time. It notably shows that, early on, most space organizations tended to design, own, or operate space objects, such as

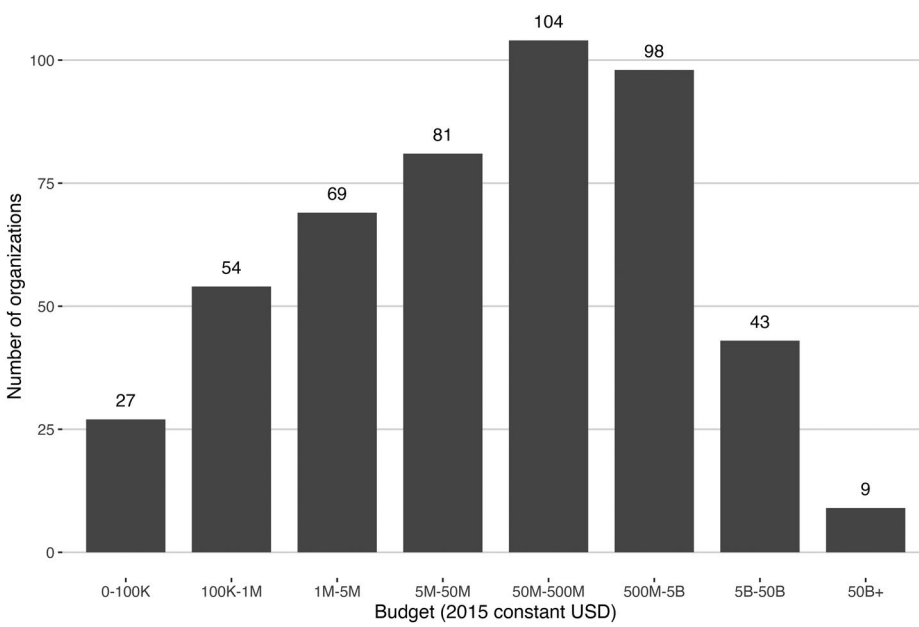

Figure 5. Distribution of space organizations by their budget in 2020.

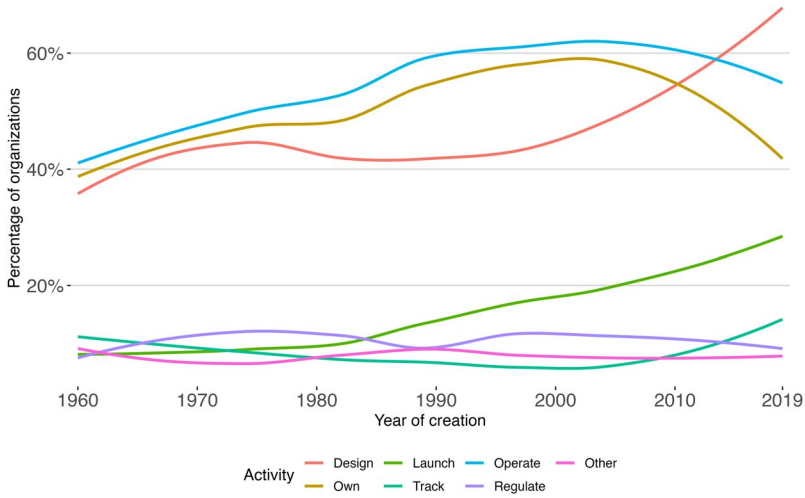

Figure 6. Evolution of the share of activities performed by new organizations (1960–2019).

satellites, but significantly fewer would be involved in their launch. Starting in the 1990s, the number of organizations launching satellites, however, grew consistently. Apart from SpaceX launching low Earth orbit telecommunication satellites, other PSOs or GSOs increasingly launch satellites for remote sensing, weather forecasting, and many more purposes. Other interesting trends can also be observed from our data, such as the growth in the number of new organizations designing space objects and the diminution of new organizations owning or operating them. The latter may be indicative of ongoing specialization in the space industry, with a growing number of companies taking part in the design of space objects without necessarily owning or operating them themselves.

Our dataset offers unprecedented insight into the evolution of space organizations. In the next section, we use it to showcase the evolution of the population of GSOs and PSOs from 1959 to 2019. Nevertheless, while this demographic data on space populations is useful to observe to what extent the growth patterns for these two populations match our theoretical expectations, it is insufficient to uncover the role played by commensalism and symbiosis in the emergence of PSOs. To describe the role these mutualistic relations played in the growth of GSOs and PSOs, we supplement our dataset with qualitative data coming from 52 interviews conducted between August 2021 and August 2022. We identified interviewees based on their current or previous professional affiliations to organizations identified in our database, with each interview lasting an average of 45 min. We interviewed space professionals from 21 countries across Europe, North America, South America, Africa, and Asia. Among the interviewees, 14 work or have worked as CEOs of PSOs, and 14 work or have worked as senior managers of GSOs. Twelve of the interviewees held senior representative or diplomatic positions in intergovernmental organizations.[7] We asked them about the organizations that they perceive as competitors and collaborators, how they reacted to the rise of PSOs, and how they grew their activities over time. Thematic summaries were then created from the interview notes or transcripts, provided the interviewee agreed to be audio recorded.

We combine interview quotes with qualitative data on the growth of public and private space activities in the last section to detail how symbiosis and commensalism shaped their respective evolution. Before this, in the next section, we provide quantitative evidence detailing the growth patterns of GSOs and PSOs. Together, these descriptive data showcase how the emergence of PSOs follows our mutualistic argument.[8]

A census of GSOs and PSOs

From an organizational ecology perspective, GSOs and PSOs are two distinct transnational populations. Not all organizations from a given population, be it GSOs or PSOs, perform the same activities. For example, a PSO that specializes in launching rockets conducts different activities than a PSO operating satellite. However, these activities and actual consumption patterns (known as their 'realized niche' in organizational ecology), do not define their population. Instead, a population is defined by the set of resources a group of organizations can potentially consume (its 'fundamental niche'), which is derived from their organizational form.

As Hannan and Freeman (1989, p. 45, 59) argue, the delimitation of a population should be based on stable characteristics of the organizations that allow certain resources to be potentially consumed. Several space organizations conduct a diverse and fluctuant portfolio of activities. A single telecommunications company can design, launch, operate, and track space objects. This does not make it part of multiple populations. As a private company, this telecommunications company will go where it can find clients and investors. All PSOs share the same 'fundamental niche' because they can potentially expand their portfolio of activities to compete directly with other PSOs. Their population remains singular and stable over time because their organizational form is fixed. A telecommunications company keeps its corporate nature even when it expands its portfolio of activities to include remote sensing and imaging.

On the other hand, while some organizations from different populations may have similar activities, their fundamental niches remain different (Denis et al., 2020, p. 434). Even if public and private organizations operate similar satellites, they belong to different populations. Whereas GSOs always require governmental support, PSOs always depend on support from investors and consumers. Their niches partly overlap as they compete for experts, data, prestige, and other resources. Nevertheless, the competition is limited because one population cannot totally occupy the other population's niche.

Using our novel dataset of space organizations, we gain an unmatched view of the proliferation of GSOs and PSOs.[9] For this purpose, we include in the population of GSOs any space organization (see definition above) that is a governmental agency, ministry, department, or institute. We also include state-state owned enterprises in GSOs as they rely more strongly on government support than on private markets. We include in the population of PSOs all space organizations that are private or publicly traded companies, irrespective of their size, activities, and sector. Each organization is relatively autonomous from the others. For example, the US Department of Commerce and the National Aeronautics and Space Administration (NASA) are considered separate organizations even if they are part of the US government, but the NASA Applied physics laboratory is not considered an

organization autonomous from NASA. Likewise, a PSO can be owned by another PSO, but they would have to be distinct legal entities to be considered as two separate organizations. For the purpose of this study, some space organizations from our dataset, such as intergovernmental organizations, are considered neither GSOs nor PSOs.

Figures 7 and 8 present the number of organizations created in both populations every year from 1959 to 2019. Interestingly, they follow very different growth patterns. Relative to the size of each population, GSOs tended to grow at a faster pace early on and remained seemingly stable since then. Meanwhile, PSOs initially grew at a slower pace before accelerating in the 1980s and really taking off since the turn of the millennium. At the same time, the proliferation of PSOs is not an entirely new phenomenon. PSOs have been part of the space adventure from the very beginning. The first commercial satellite for TV broadcasting, Telstar, was launched as early as 1962 by AT&T (Golkar & Salado, 2021, p. 4). In the 1960s, NASA was already contracting with Lockheed Martin, Rockwell International, McDonnell Douglas, and General Dynamics Corporation to design launch vehicles. Despite all the claims of a 'new space' era, SpaceX is just the visible tip of an industry that has been growing for the last six decades.

Following the tenets of organizational ecology, we are, however, more interested in each population's growth rates rather than the aggregate numbers of new organizations created every year to explain the emergence of a new population of actors (Carroll, 1984; Hannan & Freeman, 1977, 1989). Growth rates measure the percentage change in the size of a population compared to its size in a period before. As such, they offer a better view of the unexhausted potential of an emerging population to grow and, concomitantly, when it successfully established a new niche for itself. As the number of new organizations created in a year accelerates, it indicates

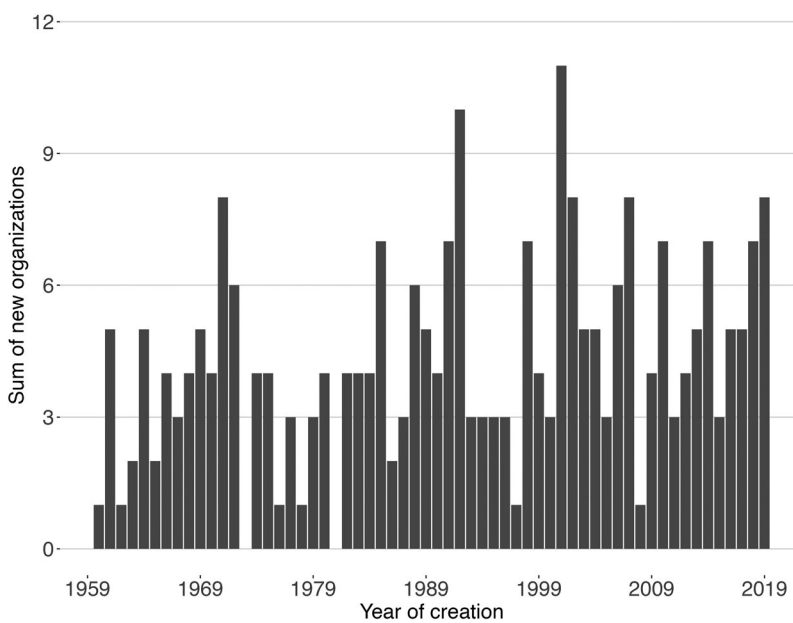

Figure 7. Aggregate number of new GSOs created every year (1960–2019).

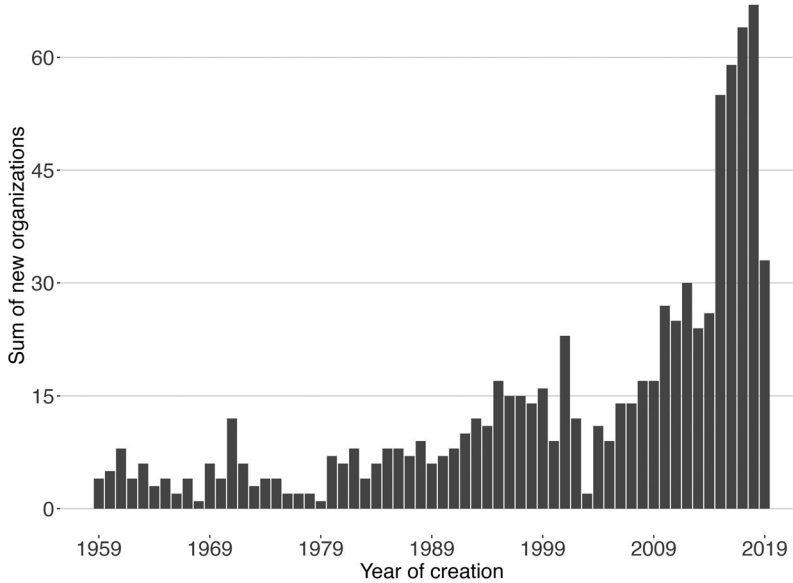

Figure 8. Aggregate number of new PSOs created every year (1960–2019).

that its organizational form is gaining in legitimacy and securing its own separate niche. Once it stabilizes or diminishes, it suggests that resources available in this new niche are becoming scarcer, suggesting a more competitive environment. Growth rates are also less sensitive to the overall size of the population's niche and are better suited for comparisons across populations. As illustrated in Figures 7 and 8, the populations of GSOs and PSOs strikingly differ in their size. In effect, there were 258 GSOs compared to 819 PSOs created between 1959 and 2019.

We calculate each population growth rate by dividing the net number of organizations added in a year (i.e. the number of new organizations created minus those that ceased their activities) by the total number of organizations existing the year before. We multiply the result by one hundred to get the percentage. The growth rate could theoretically be negative if more organizations ceased their activities than were created in a year.[10] Figure 9 plots the trend in the average growth rate for PSOs and GSOs since 1959. To smooth the yearly variations in growth rates, we calculated a rolling average over a five-year period.[11] We set the four years before 1959 to 0s. Finally, the two lines represent the LOESS regression line that best fits the growth rates calculated for each year.

The graph broadly shows an inverted U-shaped curve for GSOs (dashed line), peaking in the early 1960s and slowly declining since then, followed by the curve for PSOs (solid line), whose growth is still accelerating. The slower growth rate of PSOs in the early days of the space industry reflects the fact that the number of PSOs created at that time was relatively low and the pool of existing PSOs was already fairly large. At the beginning of the space era, existing companies in the field of aviation were among the first to join the space adventure. The growth rate of PSOs started to accelerate in the 1980s as they established themselves as a separate population from aeronautics. It then truly took off in the 2000s. There are early signs that the PSO growth rate could soon reach its peak and fall in the next decade. Figure 8

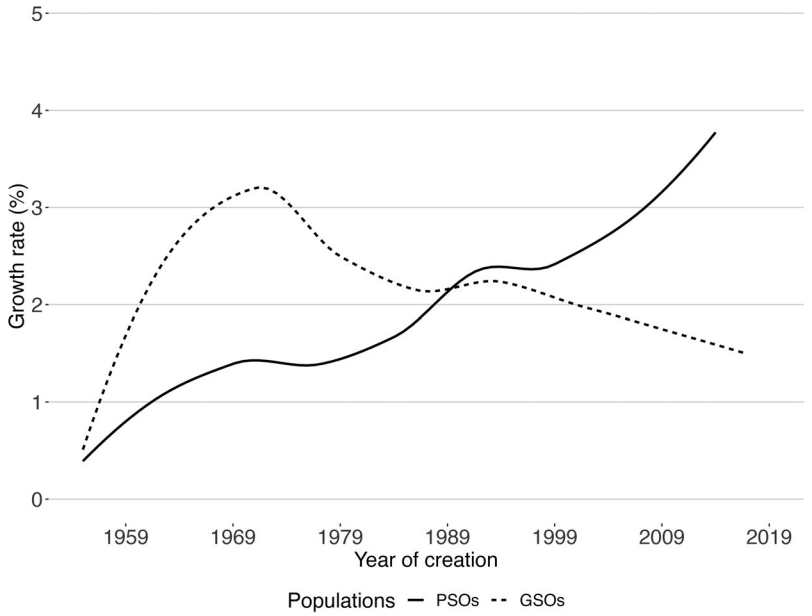

Figure 9. Evolution in the average growth rate of PSOs and GSOs (1957–2019).

shows that fewer PSOs have emerged in the last year of the decade, and preliminary data for 2020 and 2021 point toward a similar trend. Overall, these trends are consistent with the twin effects of legitimacy and competition, as proposed by organizational ecology explanations looking at individual populations. Each population's growth rate accelerates as its organizational form gains legitimacy and slows down as competition intensifies.

Consider first the population of GSOs. Back in the 1950s, few states had a space program. The idea of investing taxpayers' money in a space program was highly audacious. As Musgrave and Nexon report (2018, p. 592), the Kennedy administration thought that Project Apollo was a 'colossal waste of resources' and that only a symbolic competition with the Soviet Union made it worthwhile. Following the creation of NASA in 1958, other countries set up similar space agencies, including Indonesia (1963), Denmark (1966), and India (1969). Gradually, it became legitimate for governments, big or small, to have their own space agency (Paikowsky, 2017). It was a way to signal their economic development to both national and international audiences. Some of the most recent space agencies emerged in developing countries, including Rwanda in 2020, the Philippines in 2020, and Sri Lanka in 2021. They generate a sense of national pride and help developing countries gain worldwide recognition (Gilady, 2018). However, the signaling benefits of creating new space agencies diminish over time, and competition to oversee a finite number of space projects intensifies.

Despite being created nationally, GSOs fundamentally operate in a transnational context. Projects conducted by space agencies from one country create benefits that can be shared with other countries either freely or against compensation. As more space agencies are created, individual countries weigh the benefits of creating their own against relying on those of other countries at a lower cost. At one point, these

redundancies become too wasteful to be sustainable and competition becomes unbearable, leading to fewer space agencies being created. In other words, the pool of legislative support and public funding for space agencies reaches a limit globally. We notably see this in the choice by many countries to rely on the navigation system or situational awareness programs developed by other countries. Similarly, several space agencies, notably in Japan, China, and India, are now competing to produce a detailed map of the moon, and we can expect multiple countries to rely on their work rather than doing the same. The up- and downward trends in the GSOs' growth rate curve reflect this change, in line with explanations based on legitimacy and competition.

Similarly, the recent acceleration in the growth rate of PSOs reflects the growth in the legitimacy of this organizational form in space activities. Despite PSOs being active in space for longer than often recognized, many space experts emphasize how the successes of companies like SpaceX gave more legitimacy to other companies, and most notably smaller start-ups, to become active in space. The successful launch of Falcon 9 by SpaceX is specifically referred to as an 'iconic symbol of entrepreneurial space' (Denis et al., 2020, p. 434). Again, current growth patterns suggest that resources remained abundant and competition limited. As highlighted in Figure 8, the growth rate of PSOs was still increasing in the last decade. At the same time, there are early signs that competition is intensifying. After reaching new highs in 2017 and 2018, the growth rate of PSOs went down to 2.5% in the last year of the decade, and preliminary data for 2020 and 2021 point in a similar direction. Just as public resources for space activities are finite, so are private ones.

The order and slope of the GSOs' and PSOs' growth rates curves presented in Figure 9 are also consistent with our argument that organizations adopt mutualistic strategies in response to competitive pressure and growing legitimacy needs. First, the growth of the PSO population only took off when GSOs were already well established and competing with each other. This is in line with the mutualistic argument that new populations in a community will emerge by interacting with older ones and providing them with new resources. Second, the tail of the curve of the GSO population is long and has been relatively stable since the 1970s, as we would expect if mutualistic relations supported the lasting growth of a population faced with competition. Third, the sharp increase in the number of PSOs since the 2000s, which was even higher than before, is indicative of symbiotic and commensal relations. Symbiotic relations provided PSOs with additional resources and commensal relations enhanced their legitimacy. Consequently, PSOs have experienced a more sustained and intense growth rate for a longer period. While indicative of these mutualistic tendencies, demographic data yet provides insufficient evidence on its own. In the next section, we draw on interview data to discuss at greater length how each type of interaction has shaped the emergence of the PSO population.

Mutualistic strategies and the emergence of PSOs

This section provides evidence from interview data that mutualistic relations within and across populations help explain the emergence of PSOs. As the competition between GSOs intensified, some organizations strategically developed symbiotic relations with PSOs. This symbiosis slowed down the decline in GSO growth and

accelerated the rise of PSOs. In addition, PSOs developed commensal relations to strengthen their legitimacy, which no longer depended on greater PSO density alone. These mutualistic strategies for coping in a competitive environment were favorable to the emergence of PSOs facing high entry costs.

Symbiosis: GSOs and PSOs mutual support

Several interviewees underlined the mutually beneficial relationship between GSOs and PSOs. These interactions go well beyond mere customer-provider transactions. Interviewees spontaneously referred to 'the most important partnership', 'a joint adventure', 'embedded collaborations', 'a secret wedding', 'must-have partners', 'a blurred line', and even 'symbiosis'. One CEO from a start-up drew a parallel with the special relationship between the East India Company and the British Crown.

GSOs and PSOs do not see themselves as direct competitors. In a few cases, they offer similar services to third parties, such as satellite launches or Earth observation services. However, our interviewees explained that they were not in direct competition because their products, services, and procedures were sufficiently different. Several GSOs deliberately avoid developing products and conducting activities that could be provided by PSOs. Since the dawn of the space age, the GSOs' main competitors are other GSOs. Whether it is to accomplish a new technological feat, set global standards, or have the upper hand in intelligence gathering, space agencies, military forces, and other GSOs compete with each other. The US-Soviet and, more recently, the US-China rivalries are the best-known examples (Morin & Tepper, 2023). GSOs from smaller countries also feel that they are competing with other GSOs that are either based in their own country or elsewhere in their region. Several interviewees insisted on this competition among GSOs.

In this context, cooperating with PSOs provides GSOs with a competitive advantage. Interviewees listed numerous benefits. PSOs are perceived as having lower operating costs, better technologies, greater flexibility, higher risk tolerance, shorter timeframes, and more specialized expertise. By collaborating with PSOs, GSOs can acquire new capabilities and free up resources, which gives them a competitive edge. It is important to note that the dual nature of space technologies means that civil capacities developed by PSOs can give GSOs a military advantage (Johnson-Freese, 2016). By cooperating with PSOs, GSOs can offer better services to their stakeholders and bring political success to the public decision-makers on whom their future depends. A partnership with SpaceX, for example, allowed NASA to end its humiliating dependence on foreign transport services to reach the International Space Station (Anderson, 2013).

In recent decades, several GSOs around the world have endorsed the development of a domestic space industry as a goal in itself (Nie, 2020). PSOs are not only seen as agile providers but also as a source of technological development that should be cultivated to enhance the competitiveness of the domestic economy. Hence, several space agencies have been given a formal mandate to support their domestic space industry. This mission also serves the interests of GSOs: if public decision-makers see political or economic gains in developing a space industry, then GSOs can strengthen their position in domestic bureaucratic games by channeling the emergence of the domestic space industry.

Similarly, PSOs derive various benefits from collaborating with GSOs. The most obvious advantage is an expansion of their resource base. Several PSOs earn a substantial share of their revenue from GSOs. For example, Lockheed Martin concluded a contract of USD 7.8 billion with the US Department of Defense to upgrade the GPS constellation (OECD, 2019). Several PSOs have expanded their resource base by selling their goods and services to GSOs from various countries. While headquartered in the United States, SpaceX accrues its revenues by providing services to GSOs worldwide.

Additional revenue is only one of the benefits that PSOs gain from cooperation with GSOs. Importantly, PSOs acquire expertise, technology, data, and know-how by working with well-established GSOs. They can also use these opportunities to recruit highly-trained personnel and gain information on upcoming governmental programs and regulations. Several interviewees stressed that PSO legitimacy is boosted by their cooperation with GSOs. As one CEO put it, they are 'ennobled by public authority'. Working with NASA is a badge of honor and a source of pride for several PSOs throughout the world. This greater legitimacy can increase the client base, facilitate the allocation of public subsidies and research grants, and attract capital investment from private and public sources. Several interviewees from PSOs stressed that working with GSOs can be challenging at times, but they all acknowledged that the benefits outweigh the costs.

GSOs use different strategies to support the development of PSOs (ESPI, 2019; Mazzucato & Robinson, 2018).[12] In some cases, GSOs act as start-up incubators. The European Space Agency, for example, has a business incubator to structure the assistance it offers to hundreds of start-ups in the form of business advice, technical support, fundraising guidance, and networking opportunities. NASA has Centers for the Commercial Development of Space to facilitate the transfer of technologies to the private sector. Likewise, China's state administration SASTIND has provided early-stage funding to Chinese PSOs, such as iSpace and OneSpace (Laskai, 2019).

In other cases, GSOs are even more directly involved in the creation and development of PSOs. GSOs first invest in research and development, then ensure that a new product or service is economically viable, before transferring the activity to the private sector. As an interviewee stated, GSOs are there 'not only to help them but to initiate their activities'. The French Space Agency, for example, created Spot Image, a private distributor of imagery from Earth observation satellites, and Arianespace, a private company offering launch services. Likewise, NASA helped create the transnational corporation COMSAT in the 1960s and transferred its remote sensing satellite Landsat to a private company in the 1980s (Weinzierl, 2018, p. 176; see also Johnson, 2004). Since the 1990s, several satellite service providers initially created by GSOs were privatized, including Intelsat, Telesat, Inmarsat, Eutelsat, and China Satcom. They were perceived as ready to compete in the marketplace, and their privatization made them even more competitive.

Another strategy to promote the space industry is to externalize research and development activities. In this model, GSOs do not hire PSOs to provide products or services based on pre-defined specifications; instead, they pay increments to PSOs upon the completion of specific goals. Consequently, PSOs have more leeway to develop their own technologies and designs, which they can use when trading commercially with third parties. Prime examples are NASA's Commercial Orbital

Transport Services (COTS) and the Next Space Technologies for Exploration Partnerships (NextSTEP) programs.

GSO-PSO cooperation has spread worldwide (Denis et al., 2020). NASA was one of the first GSOs to support the development of the private sector. When NASA was still in fierce competition with the Soviet space program, it created the Office of Commercial Programs to gain a competitive advantage. According to one interviewee, the subsequent proliferation of PSOs around NASA generated 'pressure for catching up' in other countries. Several European GSOs are endeavoring to attract foreign PSOs and develop European PSOs. Even Chinese GSOs, such as the People's Liberation Army, are now actively supporting the development of PSOs so they can compete with the US space industry (Nie, 2020). Chinese 'military-civilian integration' projects involving 'social forces' like LandSpace, LinkSpace, and OneSpace, have been inspired by the US experience of public-private partnerships (Laskai, 2019). Coming full circle, this rising US-China rivalry in outer space is now used as a justification in Washington to intensify GSOs' support for PSOs (Roper, 2019). In short, competition between GSOs helps the diffusion of policies to support PSOs.

In turn, the growth of PSOs has supported the creation of new GSOs. New Zealand is a case in point. It created its space agency in 2016 after the American company, Rocket Lab, had spent years developing launching capacities from its territory (McNeill et al., 2017, pp. 314–315). One interviewee also explained that the creation of the African space agency was 'driven by […] European industrial interests' and the desire to expand the European market by consolidating African resources. Thus, symbiosis, as a mutually beneficial strategy between two populations, can explain the long tail of the GSO curve since the 1970s, as well as the sharp rise in PSOs in recent decades.

Commensalism: the enhanced legitimacy of PSOs

Interviewees provided multiple examples of commensalism in the PSO population. One interviewee used the term 'co-opetition' and explained that 'even though two private commercial actors may be competitors, they often see some benefit in collaborating'. This commensalism is frequently institutionalized in the form of national industry associations, such as the Space Industry Association of Australia, Eurospace, or Space Canada. As in other industrial sectors, these associations defend their members' shared interests. Yet, several interviewees suggested that intra-industry cooperation is easier in the space industry than in other sectors. For example, they described how 'collaborations are a lot more frequent and a lot more natural than in other industries' and that 'space is, really, by definition, a very collaborative ecosystem'. When asked about the reasons for this high degree of collaboration, interviewees explained that the space industry remains relatively small and that it 'has not matured yet to the level of hyper-competition that other industries have reached'. This is consistent with the idea that commensalism is particularly useful when a population's legitimacy is not yet fully established and before internal competition tempers its growth rate.

Commensalism provides various benefits to PSOs, such as facilitating industry-wide data collection, pooling resources to hire shared experts, communicating to the general public, launching several satellites in a single mission, attracting workers to the industry, and participating in policymaking. Several interviewees

working for small start-ups told us that their association with large corporations enhances their legitimacy. In their view, collaborating with large corporations 'really makes a difference because they bring employees and political clout'. Moreover, large corporations' successes radiate through the entire industry. According to interviewees, 'A paradigm change occurred after SpaceX launched Falcon 9 into space', 'The arrival of SpaceX and Blue Origin opened the doors to many more actors', and 'Companies like SpaceX create a hype that attracts people to the sector'. On the other hand, working with start-ups helps well-established corporations acquire new ideas and makes them more agile and innovative. Airbus, for example, created BizLab, an accelerator program for start-ups, and Airbus Ventures, to fund and support start-ups.

The increased legitimacy that PSOs gain from commensalism helps them obtain new resources, which translates into population growth. For example, the space industry is partly competing with the terrestrial communication industry for funders, superhigh frequencies, and customers. Establishing their legitimacy is crucial so they can promote the adoption of regulatory changes to facilitate the entry of PSOs into this sector. Industry associations have helped convince regulators that PSOs 'weren't crazy, liars, or magicians'. As a result, many countries have adopted space laws and regulations in favor of the space industry in recent years. Gaining legitimacy as an organizational form has made it easier for PSOs to finance their activities. According to our interviewees, 'venture capitalists have started to invest more in […] space entities', 'investment in space has gone mainstream', and 'it has become more normal to have start-ups' in the space sector. In 2019, space start-ups attracted $5.7 billion in financing (Bryce Space and Technology, 2021), a figure that would have been hard to imagine without the commensal effort to consolidate the industry's credibility.

Beyond prevalent 'new space' narratives

Our explanation for the emergence of PSOs, based on mutualism between and across populations, differs from prevalent narratives on the emergence of new space. Public commentators are particularly keen to highlight the role of disruptive entrepreneurs in the creation of PSOs. Multibillionaires like Richard Branson (Virgin Galactic), Jeff Bezos (Blue Origin), and Elon Musk (SpaceX) are often portrayed as leading humanity into a new era of space activities. Their extraordinary vision and risk tolerance have supposedly brought their companies beyond what was previously thought technically possible, economically profitable, and even legally permissible (Financial Times, 2021). However, focusing solely on the entrepreneurial spirit of a few individuals downplays the role of environmental conditions in the emergence of PSOs. Figure 10 shows that PSOs grew simultaneously across multiple countries. This observation is inconsistent with the notion that a handful of visionary entrepreneurs are responsible for the emergence of the space industry. It points instead to an industry-wide explanation.

Other commentators have underlined the agency of political leaders, particularly in terms of investing or disinvesting in outer space activities. The Kennedy administration's decision to invest massively in space activities led to the rapid growth of the American civil space program (Musgrave & Nexon, 2018). Meanwhile, following the Challenger and Columbia shuttle accidents, the budget allocated to NASA

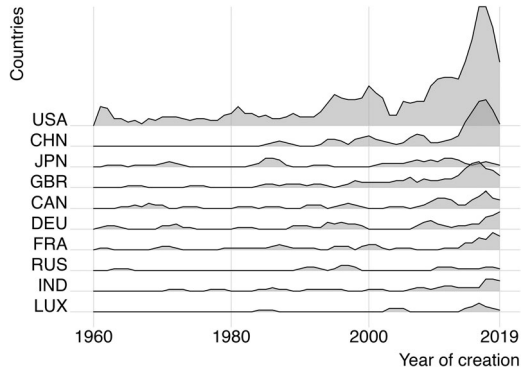

Figure 10. Three-year moving average of new PSOs in a selection of 10 countries (1960–2019).

declined for three decades, to the point that the Obama administration abandoned several projects and lost its capacity to send astronauts into space. The recent rise of PSOs in the US is sometimes described as filling the void left by this reduction in funding provided to NASA (Weinzierl, 2018, p. 174). However, this perspective overlooks that the emergence of PSOs occurred simultaneously in various countries, including those with a budgetary context differing greatly from the US.

Our explanation, emphasizing the role of mutualism, brings together accounts that focus on the agency of business entrepreneurs and political leaders by linking their respective strategies to environmental constraints. While some analysts already hinted that SpaceX's success must be understood in relation to the public support that made it possible (Anderson, 2013), we position the strategy of GSOs to partner up with PSOs as a response to a competitive environment. As resources became scarce for GSOs, they turned to PSOs to gain new space capacities. This helped PSOs' growth by providing them with various resources, including expertise, revenues, or know-how. At the same time, cooperation among PSOs increased their own pool of resources by enhancing their legitimacy and limiting costs for newcomers.

Another popular narrative emphasizes the role of new technologies in explaining the emergence of PSOs. Several technological developments, including small satellites[13] and reusable launch vehicles,[14] indeed significantly reduced the costs of taking part in space projects. For example, start-ups can build small satellites for weather purposes at a lower cost and place them in orbit as part of a broader mission sending other satellites or equipment using a launcher that other space missions could also reuse in the future. Rather than emerging exogenously and then transforming the space ecosystem in favor of private actors, the development of several key space technologies is the product of mutualistic relations between GSOs and PSOs. In the 1980s, GSOs funded the initial development of small satellites by PSOs when their commercial potential was negligible, creating a demand for private research that otherwise would not have existed (Sweeting, 2018, p. 345). Moreover, GSOs actively supported the development of reusable launchers, such as Falcon 9, which SpaceX was able to develop with the support of NASA after three failed launches on its own (Anderson, 2013, p. 267). These technologies are the product of symbiotic relations between GSOs and PSOs. They also opened the door to new commensal relations among PSOs. Companies using reusable

launchers fund their activities by offering launch services to space start-ups, and small satellite companies are able to develop their activities at lower costs thanks to reusable launchers (Sweeting, 2018, p. 358). Launch and satellite PSOs grow together, with one benefiting from the development of the other.

Therefore, it is more accurate to situate technological development within the broader context of mutualism, with endogenous interactions between the two factors, rather than supporting a naïve techno-deterministic belief that technology by itself unlocked the development of new space. A growing literature highlights how the effects of technologies in world politics must always be understood in relation to the environment in which it emerge and the actors using them (McCarthy, 2017). If new technologies alone were nevertheless the driving force behind PSOs, we should observe a rapid increase in the creation of space companies linked to specific new technologies during certain transitional periods. This is not what we see in Figures 9 and 10, which show the growth curve of PSOs becoming steadily steeper after the one of GSOs became flatter.

The glorification of a few individual entrepreneurs, accounts based solely on budgetary decisions of the US government, and beliefs in technological determinism as an exogenous force are insufficient explanations. Our theoretical framework provides a comprehensive approach that considers the integration of public and private strategies with global environmental constraints. New technologies emerge from and shape this competitive environment in which space organizations operate. These findings are in line with recent industry studies emphasizing the co-evolutive nature of technologies and both public and private actors (Gustafsson et al., 2016), as well as policy entrepreneurship literature, stressing the importance of environmental or structural variables when explaining how individual entrepreneurs can have influence (Kingdon, 1984). At the same time, our focus on mutualistic relations as strategic responses to competition adds greater agency than previous organizational ecology explanations in international studies. It recognizes the key role played by national space agencies, and chiefly NASA, in supporting the growing role of private companies in space, while also emphasizing how companies like SpaceX contributed to creating new opportunities, both for public and private space actors.

Conclusion

Two commonly held opinions on space politics appear to be at odds with each other (Cross, 2019, p. 1403; Riddervold, 2023). On the one hand, space activities are often depicted as a race between rivals, either great powers or billionaires, competing for prestige (Johnson-Freese, 2017). On the other hand, space exploration is often represented as a symbol of international cooperation for shared objectives (Cross, 2021). How can we explain that 'the main groups of people involved in space-related activity could have such radically different perspectives' (Cross, 2019, p. 1404)? This paper provides a theoretical argument and empirical evidence demonstrating that competition and cooperation are not mutually exclusive. In fact, competitive pressures can favor mutualistic relations.

Far from being outcompeted and ossified organizations, GSOs propel the development of PSOs while simultaneously benefiting from their expansion. The relationship between the two is symbiotic, as both parties gain from their interactions.

For example, NASA and SpaceX mutually benefit from each other's success, with NASA obtaining access to new technologies and SpaceX gaining new business opportunities through their collaboration. Moreover, commensal relations between PSOs have also fueled their growth, as they have cooperated to increase their collective legitimacy and access to resources. These mutualistic relationships contrast with other explanations that emphasize individual entrepreneurship or the decline of the public sector. In fact, successful entrepreneurs benefited from symbiotic and commensal relationships, while GSO decisions to establish connections with PSOs have played an instrumental role in creating mutualistic relations that contribute to the growth of both parties.

Our findings, supported by demographic and qualitative evidence, offer new insights into the interplay between structural and agent-based explanations for the emergence of new organizational forms. In their article introducing organizational ecology to international studies, Abbott, Green, and Keohane underline the structural nature of this theory (2016, p. 249). Indeed, organizational ecology emphasizes how a group of organizations shapes their evolution, rather than how individual organizations strategize, behave, and react. Our study brings agent strategies back into this structural framework by demonstrating how mutualistic relations can serve as a strategy to address a competitive environment and to increase the legitimacy of a new population in its early development.

Our analysis further suggests that combining insights from density-dependence and mutualism-based arguments in organizational ecology could prove valuable in understanding the emergence of organizational forms with high entry costs. Abbott, Green, and Keohane examine private regulatory organizations in the field of climate change and note their low entry costs (2016, p. 261), while Green and Hadden (2021) focus on environmental NGOs that also face relatively low entry costs. In contrast, in the case examined here, space organizations face high barriers to entry. Despite varying in size, space organizations typically require highly specialized expertise and significant financial resources (as illustrated in Figure 5 above). The use of mutualistic relations as strategic responses to environmental pressures appears more likely in populations facing high barriers to entry because fledgling organizations need more support to bear the initial costs and are better shielded from intense intra-population competition.[15]

There are indications that mutualism can help explain the emergence of new populations in other sectors that also faced high entry costs and were previously dominated by populations of public organizations. For example, during its early days, the Internet was dominated by a population of publicly funded research organizations (Abbate, 1999, ch. 4). The combination of high-cost infrastructure and the risks associated with its development limited the growth of a population of commercial organizations. It was only decades after publicly funded organizations joined together their various communication networks into what we now call the Internet that commercial organizations progressively emerged and targeted private consumers. Publicly-funded organizations directly supported the emergence of this new population of Internet startups by providing them with the necessary technology to operate, while gaining access to a new source of funding for their own activities. The collaboration between researchers and private vendors also helped to improve Internet technologies, as vendors discovered new problems that researchers had not considered (Leiner et al., 2017, p. 15). Furthermore, the high cost of entry

and the need to establish industry legitimacy likely contributed to the emphasis placed on interoperability by early commercial Internet organizations (Leiner et al., 2017, p. 15). Despite some tensions, mutualistic relations between public organizations and private service providers played a crucial role in the emergence of the Internet industry as we know it today.

Beyond this example, we believe our case study might also be instructive for several other cases characterized by high barriers to entry, including aviation in the nineteenth century, nuclear production in the twentieth century, and the Internet in the 20th and 21st centuries. In these sectors, private companies often made the headlines, but the active support of governmental organizations was instrumental in creating the industry in the first place (Abbate, 1999; Clarke, 1985; Van der Linden, 2002)

Future research could extend our understanding by looking at how mutualistic strategies change over time and across different populations. One potential concern about the increasing reliance of governments on private companies is that their contributions may become less visible over time as private actors gain more prominence. In many ways, SpaceX, not NASA, has become the public face of space exploration. Similarly, the names of many early Internet organizations were forgotten at the expense of companies like Google and AT&T. This trend could eventually erode the legitimacy of the population of public actors. This risk echoes the critique that states are increasingly socializing risks while allowing the private sector to capture the benefits of public investment (Mazzucato, 2011, ch. 9). However, for now, it seems that the public sector benefited from the emergence and growth of the private sector in outer space and vice-versa.

Notes

1. The dataset is available in the Online Appendices on the journal website. Users of the dataset are requested to cite this article.
2. It is important to differentiate between a fundamental niche and a realized niche: the former refers to the entire set of resources that organizations can potentially consume, while the latter is limited to resources that are actually consumed.
3. The terms symbiosis and commensalism are sometimes used to refer to different gain distributions between two populations, but we do not use these definitions here.
4. This imprint of an established population on the development of an emerging population is known as the 'priority effect' in organizational ecology.
5. A restricted definition is necessary to ensure dataset accuracy. It is reasonable to assume that the number of peripheric organizations not included in our definition is proportional to the number of organizations within our definition.
6. The dataset also includes information on the number of employees and the overall size (reflecting both an organization's budget and number of employees) of space organizations.
7. An anonymized list of our interviewees is available in the Online Appendices.
8. In this paper, we follow an analytical approach through which we consider the extent to which our mutualistic arguments help us make sense of the historical process behind the emergence of PSOs (on analyticism as a research approach see: Jackson, 2016, ch. 5).
9. For a discussion on hybrid space organizations, see Beaumier et al. (2024).
10. Our analysis is limited by the fact that we can only measure the extensive growth (i.e. the creation or termination of organizations), not intensive growth (i.e. the increase or decrease in space activities). The difficulty to find metrics for intensive growth over a long period of time is a common difficulty in organization ecology studies.
11. The results using a three-year average are broadly similar.

12. It should be noted that some GSOs limit the expansion of foreign PSOs, for example, by restricting exports and foreign investments.
13. Small satellites are significantly smaller, lighter, and cheaper to build than previous models. Since the turn of the millennium, one particular type of small satellite, called 'CubeSats', has gained prominence.
14. Reusable launchers refer to rockets that can be used multiple times to send satellites and other payloads into space.
15. Kijima and Lipscy (2023) similarly argue cooperation among international organizations is more likely when high entry costs are present.

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No potential conflict of interest was reported by the author(s).

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