# Correcting extraterrestrial externalities with satellite taxes

**Authors:** Akhil Rao, Matthew G. Burgess, Daniel Kaffine

The global rate of satellite launches is rapidly increasing, with each launch contributing to—and risking damage from—a growing buildup of space debris (Witze, 2018). If the amount of debris continues to increase, it could eventually reach a tipping point, known as Kessler Syndrome, whereby debris growth becomes self-sustaining due to collisions between debris objects. If this occurs, ceasing future launches and deorbiting active satellites may be insufficient to prevent these orbits from becoming unusable due to space debris. Currently, the quantity of annual commercial satellite launches are not controlled by any central authority, and as such each private satellite firm fails to account for the increased risk of collision their new satellite imposes on the existing satellite stock. In this paper, we show that internationally coordinated economic incentives such as satellite taxes are needed to correct these extraterrestrial externalities. Using a calibrated dynamic model of commercial launches and debris accumulation in low-Earth orbit, we quantify the costs of failing to address the space commons problem, as well as the optimal annual tax on orbiting satellites to correct the externality.

As the risk of space debris collisions has intensified, most proposed solutions have been technological: How can we better map, clean up, and steer satellites away from existing debris? These solutions include end-of-life deorbit guidelines and “keep-out” zones for active satellites, and nets, harpoons and lasers to deorbit debris. However, due to open access to orbits, technological approaches to reducing the risk of satellite collisions will induce additional satellite launches. For instance, if firms were willing to tolerate a 0.1% risk of satellite loss before the technological improvement, they will be willing to launch more satellites until the risk of satellite loss once again becomes 0.1%. This is a classic Tragedy of the Commons problem, which can be addressed in an economically efficient manner via incentive-based solutions. For instance, governments of space-faring countries could coordinate harmonized satellite taxes. As with carbon taxes, these satellite taxes could be administered at national levels and still be economically efficient, as long as they were internationally harmonized (Weitzman, 2014).

While the potential Tragedy of the Space Commons has been recognized (Adilov et al 2015, Weinzierl, 2018), to our knowledge we are the first to quantify the economic benefits of correcting it as well as the corresponding optimal policy instrument level. We develop a dynamic model of space-industry economics and debris buildup to compare the economic value of optimally-managed orbits against a business-as-usual, open-access scenario. We first calibrate the model to existing data on launches by fitting the observed data to a model of open access, whereby launch decisions are fully decentralized. Using the fitted model and projections of future growth of the space economy through 2040, we project future launch rates under this open access scenario. For comparison, we also project launch rates by a sole owner who seeks to maximize aggregate economic benefits from all satellites. By comparing the outcomes under open access launch rates to outcomes under optimal launch rates, we are able to calculate the economic gains from shifting to optimal orbit management, as well as the corresponding optimal satellite tax.

Based on preliminary results, we find that failing to correct the low-earth orbit commons problem has welfare costs on the order of ~$1 billion dollars annually, starting in 2020. However, given that scheduled launches over the next few years exceed the existing satellite

stock by nearly an order of magnitude, the welfare costs associated with open access increase dramatically in the near future. Furthermore, our analysis suggests that, starting in 2020, a price of ~$1.4 million/year on each orbiting satellite (and rising over time) would provide the economically efficient incentive to achieve first-best satellite stock levels. We also show that technological solutions such as active debris removal can reduce welfare costs from failing to optimally manage the commons, but cannot achieve first-best. Finally, we also show how the costs of inaction will escalate through time.

The Tragedy of the Space Commons is an incentives problem, and therefore needs solutions that address those underlying incentives. When the Tragedy of the Commons has been addressed in other sectors (fisheries, oil, transportation), it has often been a game of catch-up, typically with substantial social costs. In contrast, with the space industry still in its infancy, there is a rare opportunity to get out ahead of the Tragedy of the Commons, if the right incentives can be put in place. Our analysis quantifies what those incentives should look like—an annual tax on orbiting satellites—as well as the costs of failing to internalize the extraterrestrial externality in low-earth orbit. Of course, the international nature of the space industry poses challenges to implementing such pricing systems, but these challenges need not be insurmountable. In particular, Articles VI and IX of the Outer Space Treaty may provide the necessary framework for an internationally harmonized satellite tax schedule.

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