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Dissertation Abstract

My dissertation examines the economics of orbit use. Orbits of planetary bodies are congestible resources. Orbiting satellites face the risk of colliding with other satellites, and objects left in orbit can stay there for hundreds or thousands of years. The current legal environment on Earth precludes efficient allocation of orbital paths through property rights and markets, making Earth's orbits an open access commons. This problem is made worse by the possibility of Kessler Syndrome - a cascade of collisions between objects in orbit, each collision producing many fragments and increasing the likelihood of another collision. In my dissertation I develop a recursive dynamic economic theory of orbit use, examine policy choice tradeoffs and the effects of active debris removal technologies, and measure the social welfare losses from open access along with an optimal corrective tax.

In the first chapter, my coauthor and I study the economic dynamics of open access and socially optimal orbit use. We develop formal results and economic intuition for the nature of equilibrium congestion in orbit under rational expectations, and consider the effects of different time-varying physical and economic processes on open access orbit use. We show that the equilibrium collision risk under open access will be determined by the excess return on a satellite and that the economic feedback from expected congestion cost to profits can short-circuit explosive debris growth. However, firms under open access will not internalize longer-term debris accumulation. Consequently they may cause Kessler Syndrome despite limiting launches in response to collision risk. Increasing the decay rate of debris (e.g. through deorbit guidelines) or decreasing the amount of launch debris generated (e.g. through technological advances) may exacerbate equilibrium congestion due to short-run responses. The interaction between debris accumulation, collision risk, and profit maximization may also cause persistent endogenous fluctuations in orbital stocks around the steady state. This chapter connects to the literatures on orbit use, common resource problems, and economic dynamics.

In the second chapter, I derive economic principles governing the choice of space traffic control policies. I show that policies which target satellite ownership, such as satellite taxes or permits, achieve greater expected social welfare than policies which target satellite launches, such as launch taxes or permits. Price or quantity policies can achieve equal expected social welfare due to the symmetry of uncertainty between regulators and firms. I also show that active debris removal can reduce the risk of runaway debris growth no matter how it is financed, but can only reduce the risk of satellite-destroying collisions if satellite owners pay for removal or if competition from removal-induced entry reduces the returns to satellite ownership. My results show that attempts to control orbital debris growth and collision risk through launch fees or debris removal subsidies may be ineffective or backfire. To handle dependence and heterogeneity in the evolution of the collision risk distribution over time, I develop a new simulation algorithm which has a pleasingly parallel component and leverages machine learning methods for high-dimensional regressions with a one-way multigrid method for dynamic optimization. This algorithm has applications to generating impulse reponse functions in dynamic economic models with endogenous shock distributions and learning. This chapter connects to the literatures on orbit use, policy design under open access, technological solutions to global commons problems, and computation of dynamic economic models.

In the third chapter, my coauthors and I measure the marginal external cost of satellite launches and quantify the inefficiency of current low-Earth orbit use. We calibrate the physical parameters using time series' of active satellites, debris, and the European Space Agency's ECOB risk index, and the economic parameters using aggregate cross-sectional sectoral revenues. This calibration allows us to project the time path of social welfare losses from open access and the time path of an optimal corrective satellite tax from 2018 to 2040. This chapter connects to the literatures on orbit use, congestion measurement,

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and integrated assessment modeling.