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THE ECONOMICS OF SPACE DEBRIS: ESTIMATING THE COSTS AND BENEFITS OF DEBRIS MITIGATION

Abstract

This paper provides a first attempt to formally model, and quantify, economically efficient policies to address externalities from space debris. We develop an analytical model that includes debris cascade and new generation of mission-related and fragmentation-related debris. We then derive empirically tractable formulas for several hypothetical policy interventions including (i) an optimized set of launch taxes, and various ex ante and ex post rebates, to promote debris mitigation; (ii) technology standards imposed under voluntary or mandatory regulatory approaches; and (iii) optimal penalties for debris generation that might be imposed ex post under a liability system. The formulas are implemented following an extensive estimation of parameter values compiled from debris generation models, engineering analyses of mitigation/adaptation technologies, productivity losses from collision risk, and spacecraft fleet projections.

Assessing the optimal policy trajectory to address a stock pollutant like space debris requires a dynamic optimization framework. However, given that the rate of debris accumulation is non-linear in the spacecraft fleet (because the generation of fragmentation debris increases with increases in the fleet and with debris cascade) a model with many time periods must be solved computationally, with considerable loss of transparency and intuition. Moreover, this model would be extremely complex, given the need to keep track of craft with different vintages, as the incentives for incorporating debris mitigation/adaption technologies into new craft change over time.

However, we can learn a great deal from an analytical, empirically tractable model, with two time periods representing (in our case) time blocs up to and after 2030, and where variables are averaged over the time bloc. Our formulas provide considerable insight on the costs and benefits of a range of policies in the near and medium term.