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Modelling Rational Exemption to Vaccination

Vaccines have represented a major achievement of mankind, and central factors in the improvement of the standards of living and health. Major examples of this success are the eradication of smallpox, and the forecasted eradication of poliomyelitis and measles. Despite this, modern countries are progressively facing the challenge of "rational" exemption, i.e. the parents' decision to not immunize their children as a consequence of a rational comparison between the risk of infection and the risk of getting side effects from vaccination. Thanks to decades of sustained vaccination in modern industrialised societies the latter risk is often perceived to be much higher compared to the risk of infection, thereby creating the conditions for coverage decline. Rational exemption is empirically documented by surveys of vaccine attitudes suggesting that richer or more educated people are those vaccinating less. Declining coverage is therefore expected in rich countries. A variety of mathematical models are used to investigate the possible impact of rational exemption on the dynamics and control of childhood diseases. First we present some results for SIR models with information-dependent vaccination. The underlying idea is that under voluntary vaccination, the decision to vaccinate is formed from publicly available information on factors as the disease incidence and prevalence, the disease fatality, and the incidence of side effects from vaccination. We prove various global versions of the theorem stating the impossibility to eliminate the disease in presence of rational exemption, and show the role of the various information variables in triggering "vaccination induced" oscillations with very long period. Second, we offer some new results on the game-theory approach by adding further realistic factors, such as the risk of serious disease, and a further player, the State.

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