

Abstract of the Thesis

Giacomo Masali

The diffusion of innovation is a paradigmatic complex-systems phenomenon: aggregate S-curves emerge from the interaction of heterogeneous agents, evolving technologies, institutions, and media. This thesis uses tools from complexity science to connect three levels of description that are usually treated separately: parsimonious aggregate diffusion curves, micro-founded kinetic models, and empirically grounded agent-based simulations. The first part takes a deliberately reduced-form perspective. Building on the diffusion literature in operations research and marketing, it fits a Bass-type model to SDG Index trajectories (2000-2021) for each country, treating the parameters as mechanics-agnostic summaries of aggregate dynamics. Diagnostics such as saturation time and the timing of peak annual improvement reveal that most trajectories follow the familiar pattern of slow start, acceleration, and saturation, with systematic differences across income groups and regions. This provides a quantitative baseline that complements the largely qualitative work on national innovation ecosystems and sustainability. The second part moves from description to mechanism via kinetic theory. Inspired by the kinetic modeling of socio-economic systems, it develops a Kinetic Innovation Diffusion (KID) model in which individuals carry a perceived value for the product and a binary adoption state. Social interaction, media exposure, and experience are modeled as “collisions” that update perceived values; in a suitable limit, the Boltzmann description yields a closed-form adoption law where the S-curve arises as a regularized incomplete gamma function with explicit dependence on media, performance, and heterogeneity. Calibrated on four benchmark consumer durables, the KID model matches or outperforms standard Bass-family models and supports an early-stage forecasting scheme that combines pre-launch belief data with a small number of sales observations. The third part extends this kinetic framework to expectations and technological performance, providing a micro-founded model of the Gartner Hype Cycle, whose original formulation remains largely heuristic and empirically debated. Mean perceived value among non-users (expectations), adoption, and realized performance are coupled in a dynamical system: media and word-of-mouth raise expectations; adoption exposes users to realized performance; if performance lags expectations, negative feedback generates a crash and subsequent recovery. In a deterministic limit, this structure yields transparent conditions on the relative growth of media, adoption, and performance for the peak and the trough; reintroducing heterogeneity restores smooth S-shaped adoption. A Direct Simulation

Monte Carlo implementation shows that hype-disappointment-recovery patterns persist without artificial time-scale separation and even under constant media, turning the Hype Cycle from a descriptive curve into an emergent behavior with falsifiable implications. Finally, the thesis grounds these mechanisms in an agent-based model of Connected, Communicative, Automated Mobility diffusion in Europe, using a synthetic population derived from focus-group data on socio-demographics, mobility habits, and attitudes. Agents have mobility priorities and a sentiment toward CCAM; the service is characterized by performance and communication parameters. The model jointly captures mode choice and adoption/abandonment of CCAM, with sentiment evolving through experience and word-of-mouth, echoing the hype dynamics analyzed earlier. Scenario analysis shows that increasing CCAM speed alone yields progressively more successful diffusion but limited and fragile mode shift away from cars; to meaningfully reduce car use, CCAM must also improve reachability and comfort, which are dominant priorities for car users. More broadly, the ABM acts as a scenario laboratory where product design and communication strategies can be stress-tested against heterogeneous preferences and expectations. Overall, the thesis advances a unified view: diffusion of innovation is best modeled as a complex system. Aggregate S-curves, kinetic equations, and agent-based simulations are not competing paradigms but complementary lenses on the same process, enabling richer description, mechanism-based explanation, and policy-relevant experimentation under uncertainty.