**The Joint Diffusion of an Open Digital Platform and its Complementary Goods:**

The Effects of Product Ratings and Observational Learning

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**Abstract**

Platform-mediated networks are ubiquitous in markets for digital goods such as PC operating systems, web browsers, mobile phones, video games, and search advertising, among others. Here platform owners (e.g., Apple, Google, Mozilla.org) may grant access to platforms, or *open* platforms (i.e. entrust the control of them) to third-party developers (e.g., content and application developers), who in turn build complementary products upon the platforms. Unlike regular markets, platform-based markets are often multi-sided, where the platforms serve multiple agents such that the participation one agent raises the value of participating for the other(s). For example, a large installed base of Mozilla Firefox users can not only increase the adoption of Firefox browsers, but they can also attract third-party developers, leading to further creation and adoption of complementary items (e.g., add-ons), which then attract more users to Firefox. That is, both direct and indirect network effects are often key features of platform markets, and hence the diffusion of a platform and its complements are *interdependent*. Moreover, in the case of an *open platform*, this joint diffusion depends largely on the free contribution of both users and third-party developers, who are the true sources of an open platform’s growth, improvement, and innovation over time. For example, in an open system (e.g., Mozilla.org, Google) with lax central controls, *user generated feedback* becomes a vital means through which platform owners and users can screen low-value (relevant) complements. Similarly, it is often members of the developer community who freely review and decide whether to accept unto the platform complementary items submitted by their peer developers, in a manner analogous to the self-organized, peer review process in academia.

Thus, given the novelty of open innovation (e.g., self-organization and the roles of user content), we extend the Bass Diffusion Model (BDM) to study the joint or interdependent diffusion of an open, digital platform and its complementary items. In our model, we capture this interdependence (i.e., indirect network effects) by allowing the market size of the complement to evolve over time as more users adopt the platform and platform adoption to increase as the more complements are added to the platform. We, then, investigate the roles of user-generated signals such as product ratings, observational learning, and usage levels on platform-complement adoption. We consider, too, features of an open innovation that could affect diffusion. For example, the preferences of developers, the features of the add-ons they create, their choices of open source licenses, and their preferences for different types of compensations are all factors that could influence innovation success. Moreover, the model helps us examine the role of the self-organized process open platform owner use to determine which complements get accepted unto the platform.

Finally, we apply our diffusion model to a unique data set of daily downloads over 5 years for the Firefox browser (platform) and 52 of its add-ons (complements). For estimation, we re-cast the resulting 53 BDM differential equations into non-linear, discrete-time, state space forms; and then estimate them using an MCMC approach to the Extended Kalman Filter. Unlike continuous-time filters the procedure used here avoids numerical integration at every time period, and so is more computational efficient, given our lengthy time- series. Results show, for example, that observational learning increases the demand for Firefox add-ons, and add-ons increase the market size of the platform. We find, too, that a slow add-on review process can diminish platform success. Our results should be of interest to academics and members of the open source community.

**Keywords:** diffusion of digital goods; open source platform; complementary products; observational learning; experience goods; product generations; churn; platform competition; Extended Kalman filter; Markov Chain Monte Carlo