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Author(s)	Schaarschmidt, Mario; Stol, Klaas-Jan; Walsh, Gianfranco; Bertram, Matthias
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Lead Users' Innovative Work Behavior in Digital Platform Ecosystems: A Large Scale Study of App Developers

Completed Research Paper

Mario Schaarschmidt
University of Koblenz-Landau
Institute for Management
Universitätsstraβe 1
56070 Koblenz
mario.schaarschmidt@uni-koblenz.de

Klaas-Jan Stol
Lero, the Irish Software Research Centre, University College Cork
School of Computer Science and Information Technology
k.stol@ucc.ie

Gianfranco Walsh
Friedrich-Schiller-University of Jena
Carl-Zeiss-Straße 3
07743 Jena
walsh@uni-jena.de

Matthias Bertram
Hochschule Bonn-Rhein-Sieg
Grantham Allee 20
53757 Sankt Augustin
matthias.bertram@h-brs.de

Application developers constitute an important part of a digital platform's ecosystem. Knowledge about psychological processes that drive developer behavior in platform ecosystems is scarce. We build on the lead userness construct which comprises two dimensions, trend leadership and high expected benefits from a solution, to explain how developers' innovative work behavior (IWB) is stimulated. We employ an efficiency-oriented and a social-political perspective to investigate the relationship between lead userness and IWB. The efficiency-oriented view resonates well with the expected benefit dimension of lead userness, while the social-political view might be interpreted as a reflection of trend leadership. Using structural equation modeling, we test our model with a sample of over 400 developers from three platform ecosystems. We find that lead userness is indirectly associated with IWB and the performance-enhancing view to be the stronger predictor of IWB. Finally, we unravel differences between paid and unpaid app developers in platform ecosystems.

Keywords: Lead userness, digital platform ecosystem, innovative work behavior, structural equation modeling

Introduction

The success and sustainability of digital platforms are largely dependent on their innovation ecosystem (Eisenmann, 2008; Gawer and Cusumano, 2014; Nambisan et al., 2018; Roma et al., 2016). For (vertically) open and digital platforms such as social networks (e.g., Facebook) and mobile platforms (e.g., iOS), one key group of stakeholders are third-party developers (so-called platform *complementors*) that create applications that extend and run on the platform—so-called '*apps,*' *extensions*, or *plug-ins*—through extension points (application programming interfaces, APIs) that platform operators provide. These extensions enrich the platform and therefore increase its value (Basole and Karla, 2011; Ghazawneh and

Henfridsson, 2013; Sørensen et al., 2015), which in turn may retain and attract new end-users. End-users 'compose' their personalized systems based on a certain platform, and a selection of third-party applications or extensions that are available for that platform. Platform operators, such as Google (for Android), Apple (for iOS), and Microsoft (for Windows) have limited resources to keep the overall offerings of the platform attractive to end-users, but perhaps more importantly, they can leverage the expertise and creativity of *"large, varied, and uncoordinated audiences"* (Zittrain, 2006) of developers (Tiwana et al., 2010; Yoo, 2013). By vertically opening the platform to third-party developers, companies may give up their monopoly on exploiting the platform and creating value, but simultaneously they increase the platform's overall value creation opportunities (Parker et al., 2017). Instead of taking a large piece of a rather small cake, with open platform models, one can take a smaller piece of a much larger cake. Hence, for platform operators that rely on such a developer community, it is of great interest to understand how developers' innovation can be stimulated and harnessed.

There has been increasing attention for the role of platforms in digital innovation. The literature has noted a shift from modularity to a "*layered modular architecture"* (Yoo et al., 2010), and from modularity to *"generativity,"* (Yoo, 2013; Zittrain, 2006), which refers to a focus on leveraging unplanned creation of products and services by an unknown workforce, that sits *"beyond the boundaries of the organization"* (Bosch, 2012). In this paper, we adopt Tiwana et al.'s (2010) definition of a software platform as: *"the extensible codebase of a software-based system that provides core functionality shared by the modules that interoperate with it and the interfaces through which they interoperate."* The opening up of platforms has enabled third-party software providers (an unknown workforce) to leverage the platform functionality to create new products and services. The creation of said products and services is, however, not limited to this type of developers, but is also available to *users* of the platform. Many users simply use a platform and its extensions, but some categories of users may wish to extend the platform to satisfy their own user needs. Von Hippel (1986) coined the term "lead user," which he defined as users exhibiting two characteristics: (1) they *"face needs that will be general in a marketplace—but face them months or years before the bulk of that marketplace encounters them,"* and (2) they *"are positioned to benefit significantly by obtaining a solution to those needs."* The lead user concept is particularly relevant to high-tech industries where technology advances at a rapid pace (von Hippel, 1986), which is why we argue the lead user concept is particularly relevant to the fast-paced software industry.

In this paper, we focus on third-party software platform developers as "lead users" (Hienerth and Lettl, 2017; von Hippel, 1986) and seek to investigate psychological rationales that may explain their innovative work behavior (IWB). IWB is defined as *"an employee's intentional introduction or application of new ideas, products, processes, and procedures"* (Yuan and Woodman, 2010, p. 324). In the context of platform ecosystems, IWB can be defined as the extent to which third-party developers invent and generate new problem-solving ideas and transform these into new products and uses of the platform. In particular, we seek to understand how the link between *"lead userness"* and IWB is mediated from the perspective of expectancy theory (Vroom, 1964) and from a social-political perspective (Yuan and Woodman, 2010).

Understanding what drives lead users to exhibit IWB is of high conceptual and managerial importance for platform operators. Conceptually, gaining a better understanding of the underlying rationales and conditions of how lead userness transforms into IWB helps IS scholars to move beyond mono-causal attempts to explain developer participation. Managerially, such research is important because platform operators may identify new ways to further stimulate third-party contributions by an unknown workforce (cf. Ågerfalk and Fitzgerald, 2008). It is essential to attract new, and retain existing end-users, and third-party extensions can help to achieve this goal. For example, games developed for Facebook by Zynga, such as *Farmville* or *MafiaWars*, have previously helped securing Facebook's growth (Forró et al., 2012), which is important for Facebook as some news reports have suggested that the platform's growth is slowing down. Thus, as much as in other domains such as services (Stock, 2015), developers' IWB is a key attribute that helps to grow and sustain a dynamic platform ecosystem.

Against this background, this paper makes three contributions. First, by studying lead userness and IWB through a sample study of 407 developers that create applications for the Apple iOS, Android, and Facebook platforms, this study contributes to the increasing body of research on IWB of third-party platform ecosystem contributors. Second, by introducing an efficiency-oriented and a social-political perspective on paths towards IWB (Yuan and Woodman, 2010), this study contributes psychological rationales to the academic discourse, which unravel micro-processes that might help platform operators stimulate third-party participation and innovation. Finally, by distinguishing paid from unpaid developers this study contributes to a better understanding of the circumstances under which lead userness is associated with IWB (Schweisfurth, 2017).

The remainder of this paper is organized as follows. In the next section we briefly review prior work on the key themes of our study, namely digital platforms, lead userness, and IWB. We then develop a theoretical model drawing on lead user theory and expectancy theory. The following section discusses the evaluation of the theoretical model using structural equation modeling based on a sample of over 400 developers. We conclude with a discussion of our findings, limitations of the study, and an outlook to future work.

Background

Digital Platform Ecosystems

There has been a clear shift from traditional information systems infrastructure, which are fully controlled by its owning corporation with a clearly defined boundary, to digital platforms that are opened up, inviting third-parties to contribute extensions, and whose boundaries cannot be defined in advance (De Reuver et al., 2018; Yoo et al., 2010). Frequently cited examples of digital platforms include iOS (Apple), Android (Google), and Facebook, but countless other examples exist (Remneland-Wikhamn et al., 2011). These platforms represent the foundation of a wider software ecosystem, which attracts third-party developers to develop and offer extensions. Such ecosystems have also been called *value networks* (De Reuver and Bouwman, 2012; Morgan et al., 2012).

Companies create and open up their digital platform ecosystems because it provides an efficient way of extending and improving the platform as well as increasing the number of users that actively engage together to add value (Hanssen, 2012). Platform operators do not have sufficient capacity to create all functionality (Bosch, 2012), but more importantly they would not be able to identify all users' potential needs—effectively achieving what Chesbrough (2006) coined "open innovation." By inviting third parties to provide extensions, the overall platform becomes more valuable; the more "value" the ecosystem offers, the more attractive it becomes to potential users. This in turn facilitates mass customization (Piller, 2008) as each user can compose a unique personal configuration of a solution comprising the platform and a selection of extensions. Likewise, with a larger user-base, a platform offers more business potential through sales of extensions. Hence, digital platform ecosystems are "generative" (Zittrain, 2006), in that the extensions are unplanned and do not have clear boundaries as there is an "unknown" workforce of third-party developers. This paper focuses on one group of these developers: lead users, introduced next.

Lead Users

The concept of lead users was coined in von Hippel's seminal article (von Hippel, 1986). Lead users differ from "typical" end-users in that they demonstrate behavior that cannot be explained by traditional adoption research. Lead users are persons that share two important characteristics: in a given domain, they are (1) ahead of the trend, and (2) expect high benefits from innovative solutions in that particular market, which they either contribute themselves, or are eager to see implemented soon (Franke et al., 2006; Hienerth and Lettl, 2017). Trend leadership, the first dimension of the lead user construct, is associated with "already living in the future." The second dimension, high benefit expectations, implies that there is a high need for problem solving on part of the user (Franke and von Hippel, 2003).

Hienerth and Lettl (2017) offer a typology based on these two dimensions, and define four types of users. We adopted this typology and applied it to digital platform users (Fig. 1). This typology positions lead users and contrasts them with three other types of users: regular platform users (low trend leadership, low expected benefits), expert platform users (high trend leadership, but low expected benefits), and user innovators, or what we have termed *platform "power users"* within the context of platform ecosystems (low trend leadership, but high expected benefits). Furthermore, Hienerth and Lettl (2017) identified four key features that characterize lead users. First, lead userness is *domain-specific*, which means that the concept is not a *general* characteristic of a person. A person can be a lead user in one or more domains, but at the same time be a regular user (adopter) in other domains. Second, the lead user construct is *trend-specific*. Third, the lead user construct is rather *gradual*, indicating a degree of trend leadership and high benefit expectations in contrast to dichotomous characteristics (e.g., one is an adopter or not). Finally, the construct

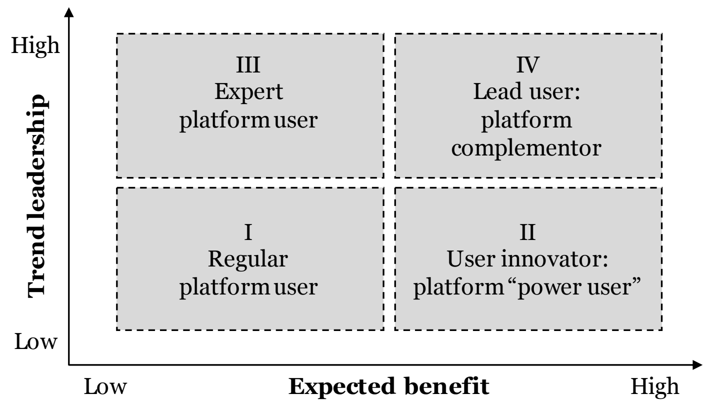

Figure 1. A typology of users based on the two dimensions of the Lead User construct (Adapted from Hienerth and Lettl, 2017)

is not a *permanent trait*, but rather an *emergent attribute*: individuals can become lead users within a domain, but their status as lead user may decline over time.

The lead user concept has emerged out of a distinction between producers (with a high level of solution knowledge, but a low level of "need" knowledge) and consumers (with typically low solution knowledge but high need knowledge) (von Hippel, 1986). Lead users are those who deviate from "typical" consumers as they also have considerable levels of solution knowledge. However, these individuals are not necessarily located outside companies' walls (Schweisfurth and Raasch, 2015); company employees can also be lead users of the company's products. Schweisfurth (2017) labeled these employees *embedded lead users*.

Innovative Work Behavior

While some notable economic research investigates motives for external developers (e.g., Boudreau, 2010; 2012), the underlying psychological mechanisms that drive innovative developer behavior in open platforms remain opaque. While platform characteristics such as perceived openness have been studied in this context (e.g., Benlian et al., 2015; Boudreau, 2018; Brunswicker and Schecter, 2019; Schaarschmidt et al., 2018), motivational factors of third-party developers have largely been neglected (Goldbach and Benlian, 2015).

Various streams of literature have identified antecedents to IWB in different contexts. These literatures have addressed a wide range of situational aspects such as a dissatisfaction with the status quo (Yuan and Woodman, 2010), the role of supervisors (De Jong and Den Hertog, 2010), leadership styles (Yidong and Xinxin, 2013), social technology motivators (i.e. optimism and innovativeness) and inhibitors, such as discomfort and insecurity (Stock and Gross, 2016). Raasch and Schweisfurth (2015) further studied lead userness among outdoor sports employees as an antecedent to IWB. Lead userness is a context-related concept (Hienerth and Lettl, 2017), describes a person's emergent characteristic to be a trend leader as much as expecting high benefits from innovative solutions. Lead userness is of high interest to researchers and managers alike, as it may reduce cost and uncertainty of customer acceptance involved in innovation (Ye and Kankanhall, 2018), and because ideas by lead users are more likely to be implemented than ideas by normal users (Schweisfurth and Dharmawan, 2019). Yet, it is unclear whether lead userness drives IWB in digital platform ecosystems, and if so, what its underlying psychological processes look like.

Theory Development

Lead Userness and Innovative Work Behavior

Our theoretical model builds upon the distinction between two alternative pathways that might stimulate IWB (Schaarschmidt, 2016; Yuan and Woodman, 2010), and which also align with the two dimensions of lead userness. The first path, referred to as the "efficiency-oriented perspective," rests on the assumption that employees display IWB as a consequence of expected positive performance outcomes (EPPO) from their behavior. Employees engage in IWB because they expect to benefit from innovative solutions that might result, which makes their work life easier. The second path is "social-political" in nature and explains IWB as a result of status and reputation-seeking (and reputation-maintaining) behavior. In our conceptual model (Fig. 2), we theorize that lead userness is associated with IWB, and that this relation is mediated by two constructs that reflect these two underlying paths.

In particular, as an exemplar of the efficiency-oriented perspective, we test EPPO, defined as employees' expectations that innovative behavior might result in increased job performance (Yuan and Woodman, 2010), and as an exemplar for the social-political path, we test reputation as innovative (RAI) (Yuan and Woodman, 2010). These constructs align conceptually well with the trend leadership dimension (i.e. RAI) as well as with the expected benefit dimension (i.e. EPPO) of lead userness, and are therefore ideal candidates to link research on lead userness and IWB. In addition, the model assumes differences between paid and unpaid developers, which mirrors the distinction between the "classical" notion of lead users (i.e. unpaid) and *embedded lead users* (i.e. paid), as we detail in the following.

Lead users are said to be ahead of trend and to expect high benefits from solutions in a particular market (Hienerth and Lettl, 2017). Their expectations towards solutions therefore might be explained by expectancy theory (Vroom, 1964). Expectancy theory stresses that individuals generally act on the basis of the potential outcomes they attach to their behavior. Thus, individual behavior, including choices, decision-making, persistence in goal orientation, and performance is determined by individuals' attitude towards and beliefs in how well a certain activity can be executed (Wigfield and Eccles, 2000). According to lead user theory, when app developers display high levels of lead userness, they implicitly expect high benefits from solutions they themselves provide for a particular domain (Schweisfurth, 2017). We therefore posit that app developers' lead userness relates to EPPO.

HYPOTHESIS 1 (H1): *App developers' lead userness is positively related to expected positive performance outcomes.*

Aspects of informal social reputation, which is backed by impression management literature (Bolino, 1999; Leary and Kowalski, 1990; Schlenker, 1980), might also explain IWB. Impression management theory posits that individuals are inclined to act in ways that are consistent with their self-perceived social image. One such image in an innovation context is having a reputation as innovative (Yuan and Woodman, 2010). When individuals perceive themselves as a source of novel ideas, which are subsequently valued by peers, they are likely to invest in upholding this image. Developers that display high levels of lead userness know that they are ahead of the trend in a specific domain and tend to consider themselves as innovative, suggesting that lead userness relates positively to RAI.

HYPOTHESIS 2 (H2): *App developers' lead userness is positively related to their reputation as being innovative.*

IWB can be explained by either the performance-enhancing view or the social-political lens. In line with expectancy theory, the performance-enhancing view suggests that employees are motivated by their own expectations towards goal achievement. Thus, when they expect that engagement in IWB results in favorable outcomes for themselves, they are more likely to display such IWB (Schaarschmidt, 2016). We theorize that same rationales apply for app developers, which is why we posit:

HYPOTHESIS 3 (H3): *Expected positive performance outcomes are positively related to app developers' innovative work behavior.*

The social-political perspective provides an alternative explanation for why people engage in IWB. In particular, the impression management literature highlights that in organizational settings, employees may either exert a form of assertive impression management, that is, a tactic for deliberately improving the current social image (Bourdage et al., 2015), or a defensive impression management. We submit that people high on trend leadership, such as lead users, invest to uphold their social image as being innovative (i.e. defensive impression management), and that activities undertaken for securing this image are observable in behaviors that include idea generation.

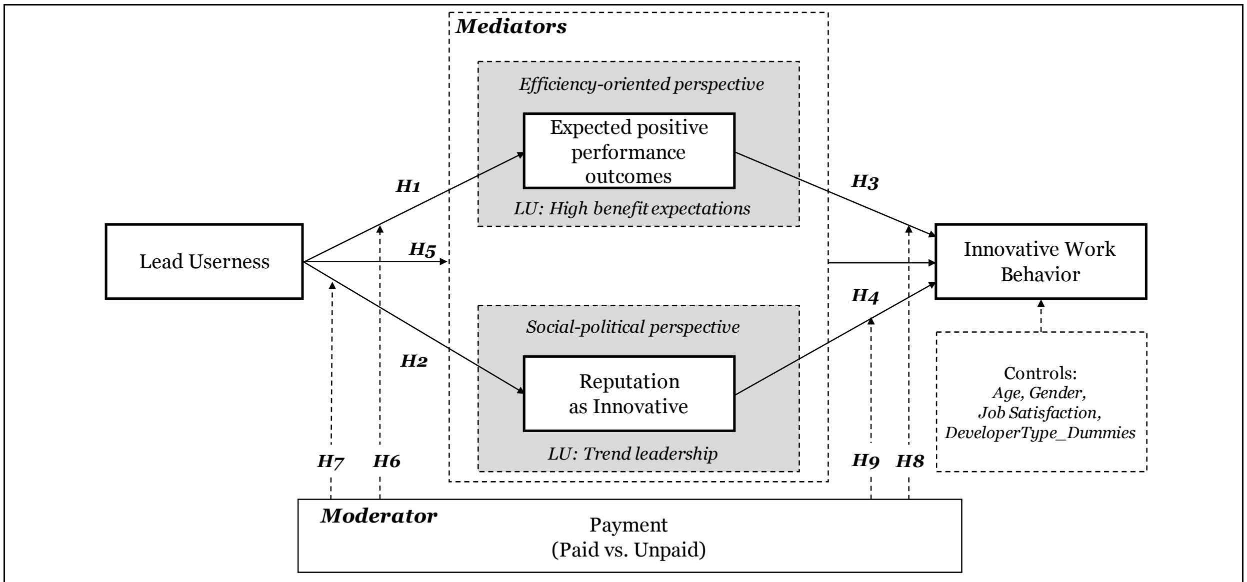

Figure 2. Conceptual Model

HYPOTHESIS 4 (H4): *Reputation as innovative is positively related to app developers' innovative work behavior.*

Generally, the literature on lead users establishes a positive relationship between lead userness and innovativeness in a given product domain (Franke et al., 2006). Similarly, Schweisfurth and Raasch (2015) showed for embedded lead users, that their degree of lead userness is associated with IWB. Drawing on these literatures, we theorize that for app developers, lead userness is equally related to IWB, but that this effect is indirect, that is, mediated by EPPO and RAI.

HYPOTHESIS 5 (H5): *Expected positive performance outcomes and reputation as innovative mediate the relation between lead userness and innovative work behavior.*

Lead Userness versus Embedded Lead Userness

While the lead user concept emerged out of a clear distinction between users (with low levels of solution knowledge, but high levels of need knowledge) and producers (with high levels of solution knowledge, but low levels of need knowledge) (Schweisfurth and Raasch, 2018), researchers have highlighted that users might also be located within the boundaries of the firm as so-called *embedded* lead users (Schweisfurth and Herstatt, 2016). At the same time, app developers, such as open source developers (von Krogh and Spaeth, 2007), are users of what they produce. To this end, we compare developers who are paid for their job, a developer group that corresponds with the notion of embedded lead users, and developers who are not paid for their job, who might be considered lead users in a classical sense (Schweisfurth, 2017). We theorize that organizational embeddedness might be a liability in the sense that status seeking in a closed circle is different from status seeking in a wider community.

To compare paid and unpaid developers (who mirror *embedded* and classical lead users, respectively), we take a recombinant view of creativity (Hargadon, 2006; Schweisfurth, 2017). This view suggests that actors with access to different knowledge domains can combine these domains to identify innovative solutions. Thus, an individual's idea generation capacity is a function of being able to reorganize different knowledge-domains. Lead users are known to have the capacity to combine the distinct knowledge domains of need and solution knowledge. Need knowledge usually accrues during product or service usage, especially when problems are recognized (Jeppesen and Frederiksen, 2006). Solution knowledge is usually a result of technological experience that rests in firms.

We argue that in their roles as users of apps and contributors, app developers generally have a high degree of need knowledge, which is even higher when they classify as lead users. At the same time, we argue that *embedded* lead users, that is, those who are paid by a firm, have access to an even larger pool of solution knowledge as their role is not only fulltime, but also within a context of a firm that may have extensive resources. Thus, their expectations towards positive performance outcomes should be higher than those for "normal" lead users. We therefore propose the following hypothesis:

HYPOTHESIS 6 (H6): *Lead userness relates more strongly to expected positive performance outcomes for paid compared than for unpaid developers.*

We also predict differences for the path from lead userness to RAI. In a community as much as within firm boundaries, impression management literature suggests that status-seeking behavior is an important driver for IWB (Gaspart and Seki, 2003). We thus theorize that lead users aim to uphold their level of RAI as a consequence of their reputation as being ahead of trend (Khan, 2017). Embedded lead users have at least two status groups for which RAI might be important: the community of app developers as well as peers within the boundaries of the firm. This dual obligation might induce paid app developers to invest more in their RAI than their unpaid peers.

HYPOTHESIS 7 (H7): *Lead userness relates more strongly to reputation as innovative for paid compared than for unpaid developers.*

Given comparable states of EPPO and RAI, the question remains how embedded lead users differ from "normal" lead users in their way to transform these states into IWB. We theorize that unpaid developers more strongly turn their EPPO into actual behavior because in contrast to their paid counterparts, they have fewer alternative ways to realize solutions to given problems (Schweisfurth, 2017). Lead users that are employed might to a larger degree trust in colleagues or "the firm" to solve a certain problem. Thus, although both developer groups' IWB is driven by EPPO, this effect is stronger for unpaid developers. For RAI, we theorize that due to their organizational embeddedness, paid developers perceive more obligations to uphold their level of RAI by displaying IWB than unpaid developers. Thus, we hypothesize:

HYPOTHESIS 8 (H8): *Expected positive performance outcomes relate more strongly to innovative work behavior for unpaid than for paid developers.*

HYPOTHESIS 9 (H9): *Reputation as innovative relates more strongly to innovative work behavior for paid than for unpaid developers.*

Method

Following prior studies of lead userness (Franke et al., 2006; Schweisfurth and Raasch, 2015), we conducted a cross-sectional survey study of third-party platform ecosystem developers. The data were analyzed using structural equation modeling.

Sample and Procedures

We conducted a survey among application developers who develop applications for three popular platform ecosystems: Apple iOS, Android, and Facebook. A standardized online questionnaire was used to target as many app developers as possible. Different methods were used to draw attention to the survey. First, a message was posted in 59 international target-group-specific forums and newsgroups; it contained information about the survey and a link to the online questionnaire. Second, we emailed student associations in the fields of computer science, business information systems, and media computer science at European universities and asked them to distribute information about the survey to students through their internal communication channels. Third, international app developers and application development companies were directly informed about the survey by e-mail. Overall, 438 respondents completed the questionnaire. After removing incomplete responses and checking for unrealistic answers, 407 responses were included in the analysis.

We were cognizant of the fact that developers might work for multiple platforms because apps have to run in different environments (i.e. be portable across iOS, Android). At the beginning of the questionnaire, we therefore asked developers to provide their answers in relation to the platform for which they develop most. Respondents that answered in relation to Apple iOS comprise the largest subgroup of the sample (60%). About 37% of the respondents indicated to work primarily for Android-based platforms. Only a minority of 3% identified themselves as Facebook developers. The average age of the developers sampled is approximately 30 years (with a mean age of 29.5). In terms of education, 19.7% of respondents have a high school degree as their highest degree, 6.6% indicated to have a form of apprenticeship; 47.2% received a Bachelor degree, 24.8% hold a Master's degree, and 1.7% indicated to hold a Ph.D. On average, respondents work 29.3 hours per week on developing apps and work on four projects simultaneously (SD=3.66). Our question about developer skills ("I would describe myself as a skilled developer") was answered as expected by a group of developers (M = 5.4, SD = 1.43). For lead userness, it is also important to know how actively apps are used by the developers themselves. Here, respondents reported an appropriate level of self-usage of apps ("I use apps that I develop myself regularly," M = 4.94, SD = 1.65).

Measures

Lead userness is a two-dimensional construct (Lüthje and Herstatt, 2004), consisting of the two components "ahead of trend" and "high benefit expectations" (von Hippel, 1986). Despite this conceptual consensus, the dominant way to measure lead userness is unidimensionally and reflectively (e.g. Jeppesen and Frederiksen, 2006; Schweisfurth and Raasch, 2015). Hence, we adopt this conceptualization and used five items measuring the high-benefit component, which we adapted from Schweisfurth and Raasch (2015). Lead userness is a domain-specific construct (von Hippel, 1986) and for that reason researchers usually use proxies to measure high-benefit expectations, such as being an intense adopter of products. For example, Schweisfurth and Raasch (2015) used questions concerning mountaineering experience (i.e. highest mountain climbed and longest mountaineering track undertaken) in a study of lead userness in outdoor sports industries. We tailored the high-benefit expectation component to our specific domain of software applications within platform ecosystems by asking for the number of apps that are intensely used by developers. Developers reported numbers ranging from zero (2.5% of the sample) to 200 with a mean of 17.6 apps. The dependent variable, *innovative work behavior*, was assessed by three items selected from Scott and Bruce (1994). We measured both *expected positive performance outcomes* and *reputation as innovative* by drawing on scales from Yuan and Woodman (2010). Among our control variables, *job satisfaction* was measured with two items adapted from Morris and Venkatesh (2010). All items were assessed with a 7-point Likert scale (1="fully disagree," 7="fully agree").

Results

Assessment of the Measurement Model

Table 1 lists the composite reliability and Cronbach Alpha values, which are two measures for internal consistency reliability. All values were well within the recommended range of 0.7 and 0.9 (Hair et al., 2011). Although an acceptable value was also achieved for Lead Userness with six items (Cronbach's Alpha = 0.78), given the low factor loading of item LU6 (loading 0.35), we excluded this item. This procedure is in line with the unidimensional nature of the construct. The new Cronbach's Alpha was 0.81.[1]

All items load significantly on their respective factor. In addition, all factor loadings are ≥ 0.6. The average variance extracted (AVE) is above the recommended threshold of 0.5 except for lead userness, which is 0.47. As it was only a fraction below the recommended threshold, we decided to retain the factor as discriminant validity is given (as we detail below) and because studies exist that have successfully applied measures that were close to the threshold (e.g., Helm, 2013).

We also assessed discriminant validity, that is, the issue of whether concepts or measurements that are supposed to be unrelated are, in fact, unrelated (Fornell and Larcker, 1981). The Fornell-Larcker criterion suggests a sufficient discriminant validity if the square roots of the AVEs are greater than all correlations of the respective construct with other constructs. This was the case for our constructs (see Table 1). Furthermore, we assessed the cross-loadings of all constructs in our model by means of an exploratory factor analysis (see Table A-2 in the appendix); none of the items loaded higher onto other constructs.

[1] To ensure the robustness of our results, we calculated all models with the original six-item scale, including the item that reflects the trend leadership dimension, and found similar results.

Table 1. Means, composite reliability (CR), Cronbach alpha, average variance extracted (AVE), and correlations among constructs

	Mean	SD	CR	Cronbach α	AVE	LU	IWB	EPPO	RAI
LU	4.61	1.06	0.81	0.81	0.47	**0.68**			
IWB	5.20	0.81	0.79	0.74	0.55	0.35	**0.75**		
EPPO	5.21	0.88	0.76	0.78	0.52	0.34	0.71	**0.72**	
RAI	5.23	1.02	0.75	0.75	0.60	0.39	0.68	0.70	**0.77**

Note: LU=Lead userness, IWB=Innovative work behavior, EPPO=Expected Positive Performance Outcomes, RAI=Reputation as Innovative. Square roots of the AVEs are listed on the diagonal (in bold).

Assessment of Factor Structures

Before data can be used in structural equation modeling (SEM), it is recommended to investigate underlying factor structures. To this end, we conducted a confirmatory factor analysis with AMOS 25 and a maximum-likelihood estimator. The model revealed a good fit with the data as indicated by χ^2/d.f. = 1.619, a comparative fit index (CFI) of 0.98, a Tucker-Lewis coefficient (TLI) of 0.97, a root mean square error of approximation (RMSEA) of 0.039, and standardized root mean square residual (SRMR) of 0.032 (Bagozzi and Yi, 1988; Kline, 2016).

Assessment of Common Method Bias

We used the same respondents and method to assess the independent variable, the mediators, and the dependent variable, which raises concerns about artificially created correlations (Podsakoff et al., 2003). We assess this possibility with two tests that are commonly used to identify common method bias (CMB). The first test we used is Harman's single factor test. The rationale underpinning this test is that if one factor accounts for more than 50% of the variance in the items used, then this may suggest the presence of CMB. In this case, a model with all items of our conceptual model loaded onto a single factor accounted for 36.2% of the variance. Though passing the Harman's single factor test is an initial indicator for the absence of CMB, the test has been criticized because large amounts of common method variance must be present before a bias occurs (Fuller et al., 2016). The second test to detect common method variance is the unmeasured common latent factor method (Lindell and Whitney, 2001; Podsakoff et al., 2003). With this test, differences in factor loadings are detected when items load on their respective construct as well as on an unmeasured common latent factor. Deviations of factor loadings of more than 0.2 are considered problematic when models with and without the common latent factor are compared. In our case, only one item for EPPO was slightly above the 0.2 threshold. Based on these two tests, we argue that common method bias did not loom large in this study.

Results of Structural Equation Modeling

To test hypotheses 1-5, we used SEM with AMOS 25 and a maximum likelihood (ML) estimator. We tested the conceptual model depicted in Figure 2, that is, including control variables (age, gender, job satisfaction, dummy_AppleDeveloper, dummy_AndroidDeveloper). The resulting model had a good fit with the data (χ^2/d.f. = 2.109, CFI = 0.95, TLI = 0.93, RMSEA = 0.052, and SRMR = 0.092). The model explained 11% of the variance in EPPO, 15% in RAI, and 66% in IWB. We note that job satisfaction had a significant effect on IWB (β = 0.47, $p < 0.01$).

In line with Hypothesis 1, lead userness related positively to EPPO (β = 0.34, $p < 0.01$). In support of Hypothesis 2, lead userness also positively related to RAI (β = 0.38, $p < 0.01$). On the right-hand side of our conceptual model, Hypothesis 3 suggested EPPO relates positively with IWB, which the data support (β = 0.49, $p < 0.01$). Surprisingly, and contrary to our expectations, there was no significant link between RAI and IWB (Hypothesis 4, RAI → IWB, β = 0.12, n.s.). Table 2 provides an overview of the SEM results.

Table 2. SEM results

Hypothesis		***β***	***CI***				***Support***
H1	LU → EPPO	**0.34*** **	[0.22; 0,46]				**Yes**
H2	LU → RAI	**0.38*** **	[0.26; 0.50]				**Yes**
H3	EPPO → IWB	**0.49*** **	[0.27; 0.69]				**Yes**
H4	RAI → IWB	0.12 n.s.	[-0.10; 0.33]				No
Mediating variables							
Hypothesis		***β***	***CI***	***β_{Paid}***	***β_{Unpaid}***	***z***	***Support***
H5	*Direct* LU → IWB	0.15*	n/a	0.10***	-0.01 n.s.	-1.54	n/a
H5	*Indirect* LU → IWB	**0.21** **	**[0.15; 0.31]**	n/a	n/a	n/a	**Yes**
Moderating variables							
Hypothesis				***β_{Paid}***	***β_{Unpaid}***	***z***	***Support***
H6	Payment × LU → EPPO			0.49***	0.38***	-0.24	No
H7	Payment × LU → RAI			0.40***	0.36***	-1.31	No
H8	Payment × EPPO → IWB			0.69***	0.84***	**1.73***	**Yes**
H9	Payment × RAI → IWB			0.13**	0.00 n.s.	-1.02	No

*Note: ***p-value < 0.01; ** p-value < 0.05; * p-value < 0.10; n.s.: not significant; standardized effects. CI=confidence interval*

Hypothesis 5 proposed a mediation effect of EPPO and RAI on the link between lead userness and IWB. We used two procedures to test for mediation effects: SEM and the SPSS macro PROCESS (Hayes, 2018; Model 4). The results are shown in Table 3. The reason for employing both procedures was to compare results, as PROCESS is able to calculate specific indirect paths while AMOS is not.

According to various authors (e.g., Zhao et al., 2010), mediation is demonstrated when the indirect effect is greater than the direct effect. If the direct effect (in this case LU → IWB, without mediators) is insignificant, then the mediation is called "full mediation" (Baron and Kenny, 1986). The results of the AMOS SEM analysis indicate that the *direct* effect of lead userness on IWB is significant ($\beta = 0.15$, $p < 0.05$), while the simultaneous *indirect* effect through EPPO and RAI is also significant ($\beta = 0.21$, $p < 0.01$). Because the indirect effect is larger than the direct effect (0.21 vs. 0.15), we follow Zhao et al. (2010) and claim support for H5.

Table 3. Mediation results

	Paths	**SEM**	**PROCESS**
Direct	LU → IWB	0.09 (0.04), p<0.05, [0.02; 0.15]	0.05 (0.02), p<0.05
Indirect	LU → EPPO →IWB	*n.a.*	0.21 (0.04) [0.14; 0.30]
Indirect	LU → RAI →IWB	*n.a.*	0.05 (0.02) [0.01; 0.09]
Indirect	LU → EPPO →IWB *and* LU → RAI →IWB	0.15 (0.03), p<0.01 [0.09; 0.21]	0.26 (0.04), p<0.01, [0.19; 0.35]

*Notes: *** p-value < 0.01; ** p-value < 0.05; * p-value < 0.10, unstandardized effects, standard errors in parentheses; lower and upper bounds for bootstrapping in square brackets where available.*

We also calculated specific indirect effects with the PROCESS macro developed by Hayes et al. (2017). Here, it became evident, that the indirect effect through EPPO (the efficiency-oriented perspective) is stronger ($\beta = 0.21$, $p < 0.01$) than the indirect effect through RAI (the social-political perspective) ($\beta = 0.05$, $p < 0.05$). The total indirect effect is (as with AMOS, $\beta = 0.15$, $p < 0.01$) positive and significant ($\beta = 0.26$, $p < 0.01$). Please note, that in Table 3, we compare unstandardized effects as this is the output PROCESS provides.

Moderation Results

To address the hypothesized moderation effects of payment (H6-H9), we conducted a multigroup analysis with AMOS (Benlian et al., 2015). We split the data set into those who were paid for their work (even if developers were only paid partially) and those who did not receive payment. The latter qualify as 'true' volunteers (Barcomb et al., *in press*). The reason to include part-time workers was that any link with an employer, even when present for a relatively short time, may prompt developers to behave consistent with employer expectations, which subsequently could affect how they rate EPPO and RAI. Of the 407 developers, 208 were paid for full-time work as app developers and 115 were not paid at all. Eighty-four respondents indicated to receive payment for some of their work. Respondents were asked to indicate the level of payment from 10% to 90%. On average, the 84 part-time workers got paid for 57% (SD=23.8) of their work on application development for platform ecosystems.

To analyze the payment moderator (paid versus unpaid), we therefore had two groups: (1) the group of 292 respondents who indicated to receive payment (208 of whom are fully paid, and 84 paid to some extent), and (2) the group of 115 (unpaid) volunteers. We conducted a t-test to assess whether these groups are different. To this end, we asked for developers' norm for payment (Alexy and Leitner, 2011). Norm for payment (Question: "I think it is OK if people get paid for working on app projects," scale 1-7) is slightly, but significantly higher for the paid developer group ($M_{paid}=6.7$, $SD_{paid}=0.63$, $M_{unpaid}=6.50$, $SD_{unpaid}=0.95$, $F=7.326$, $p=0.007$). Thus, there is reason to believe that these groups are not identical.

The multigroup model also revealed a good fit with the data ($\chi^2/d.f. = 1.570$, CFI = 0.94, TLI = 0.93, RMSEA = 0.038, and SRMR = 0.106). However, χ^2-difference tests indicate that the models are invariant. Thus, we analyzed moderation pathwise. First, we analyzed the path from lead userness to EPPO. Although the β-values are different for paid and unpaid developers, this difference is not significant (Table 2, $\beta_{paid} = 0.49$, $p < 0.01$; $\beta_{unpaid} = 0.38$, $p < 0.01$, $z = -0.24$), thus we reject H6. The same holds true for H7, which suggested a difference between paid and unpaid developers for the link from lead userness to RAI (Table 2, $\beta_{paid} = 0.40$, $p < 0.01$; $\beta_{unpaid} = 0.36$, $p < 0.01$, $z = -1.31$). However, as expected in H8, the path from EPPO to IWB is stronger for unpaid developers ($\beta_{paid} = 0.69$, $p < 0.01$; $\beta_{unpaid} = 0.84$, $p < 0.01$, $z = 1.73$). Finally, we found no support for H9. The path is significant for paid developers but not for unpaid developers; the z-score of -1.02 indicates there is no significant difference.

Discussion

Von Hippel (1986) defined lead users as having two characteristics: *"Lead users face needs that will be general in a marketplace—but face them months or years before the bulk of that marketplace encounters them, and—Lead users are positioned to benefit significantly by obtaining a solution to those needs."* Since the concept was coined in von Hippel's seminal article, it has been associated with a number of favorable outcomes such as high number of ideas provided to a firm or idea quality (Schweisfurth and Herstatt, 2016). Lead userness has also been studied in the context of employment, where employees of the firm are *embedded* lead users of the products the firm sells (Schweisfurth and Raasch, 2015). Here, favorable outcomes of lead userness include customer orientation, boundary spanning, and IWB (Schweisfurth and Raasch, 2015). However, while evidence exists for the important role of lead userness in shaping IWB for employees, research on the psychological processes that turn lead userness into IWB is scarce. Further, the lead user concept is domain-specific, and has to the best of our knowledge not yet been linked to the phenomenon of third-party platform ecosystem developers. Hienerth and Lettl (2017, pp. 7) only recently suggested that it is not always clear *"what lead users actually are."* Hence, this study defines, operationalizes, and positions third-party ecosystem developers as a specific type of lead user. As part of employing this theoretical lens, we adapted the operationalization of the construct to these "platform complementors." Specifically, these platform complementors are differentiated from platform experts or from platform "power users" (see Fig. 1).

Theoretical Implications

Our work integrates lead user theory to the IWB construct through mediation by the efficiency-oriented perspective and the social-political perspective. We drew from prior research (e.g. Yuan and Woodman, 2010) who used performance-oriented theoretical perspective and a social-political perspective to investigate individual innovative behavior, and linked these theoretical perspectives to the two key dimensions of the lead user concept: trend leadership and high benefit expectations. Our theoretical model links expectancy theory to the high benefit expectations dimension from the lead user construct, and links the social-political perspective to the trend leadership dimension. While these linkages seem quite natural, to the best of our knowledge, these links have not been empirically evaluated.

Among the most prevalent findings is that lead userness is associated with IWB in a platform ecosystem context. As our mediation analysis further revealed, this association is of an indirect nature, indicated by significant indirect effects through EPPO and RAI. Our results also showed that this indirect effect does not support a full mediation. In addition, the results revealed that despite the fact that the efficiency-oriented perspective and the social political perspective are both strong theoretical rationales that explain IWB (Yuan and Woodman, 2010), only EPPO is significantly related to IWB in app development contexts. Social rewards, however, seem to be of considerably lower importance. This reflects recent research that questions app developers' pro-social motives and proposes that the majority of developers in digital platforms tend to take specific informal (e.g., increasing design complexity) and formal (e.g. patenting) actions to capture value (Miric et al., 2019).

Managerial Implications

The lead user concept has reached quite a mature state (Hienerth and Lettl, 2017), which makes it relatively easy to identify and classify lead users, for example, by means of hot topic detection or social network position (Chen et al., 2013; Kratzer et al., 2016). Thus, market research firms aim to identify those lead users that help to provide use-related knowledge that can benefit the firm (Jeppesen and Frederiksen, 2006). In a similar vein, platform operators are able to identify lead users among their external workforce by looking at trend leadership and high benefit expectations.

Our study adopts lead user theory as a lens to understand third-party developers who contribute to platform ecosystems. In particular, platform operators that "vertically" open up their platforms invite third parties to contribute to the ecosystem through new products—in software ecosystems such as Android, iOS and Facebook we refer to these as "apps." A key reason for opening up the platform is the realization by platform operators that the value of the platform to its users will increase as the ecosystem surrounding the platform becomes an active marketplace. The potential earnings through this marketplace are shared with the third parties. Our study offers support for the positive relationship between lead users as third-party app developers pays out in increased developers' IWB. This is important as a workforce that displays high levels of IWB helps to nurture an active platform ecosystem. The results also suggest, given employees' different motivations to display IWB, that EPPO and RAI are different in their effect. Table 4 summarizes the findings of our study and offers some recommendations for practice and future research.

Limitations and Directions for Future Research

Some limitations are associated with this study that are worth mentioning because they provide fruitful avenues for further research. For example, while our measurement approach is in line with previous work for lead userness (Franke et al., 2006) and IWB (Janssen, 2005), innovation research frequently suggests to use supervisor ratings for IWB in addition to self-rated measures (Stock, 2015). Although subjective and objective measurements for IWB correlate highly, at least for the paid, embedded lead users in this study, alternative measurement forms should be tested. In addition, for our multigroup analysis, we grouped those that are paid part time with fully paid individuals. While our group of partly paid developers was comparably small (N=84), future studies with samples balanced according to this attribute could assess differences between fully paid, non-paid and partly paid developers. The measurement approach applied might also face problems of endogeneity in the sense that IWB might drive EPPO, RAI, as well as lead userness. While this issue is a problem that afflicts all cross-sectional surveys, we want to recall that lead userness as a characteristic is meant to influence IWB as a behavioral outcome. Nevertheless, future studies

Table 4. Findings and recommendations for practice and future research		
Construct	**Findings**	**Recommendations**
Lead User	The concept of lead user as operationalized within the context of platform ecosystems is positively associated with innovative work behavior.	(1) Platform operators are recommended to increase their awareness of lead users within their ecosystems so as to encourage and facilitate their activities to remain active on the platform
Role of mediators	The path from lead userness to IWB is indirect, mediated by Expected Positive Performance Outcomes and Reputation as Innovative. While a significant direct effect can be observed as well, this effect is smaller than the indirect effect.	(2) Expectancy theory and social-political perspectives should be considered in further research as they clearly play an important role in the relationship between lead userness and innovative work behavior.
Expectancy theory and Social-Political perspective	Expected Positive Performance Outcomes is a stronger mediator on Innovative Work Behavior than Reputation as Innovation, with a considerably higher coefficient (Table 3).	(3) Social rewards seem to play a much smaller role compared to developers' expected performance outcomes.
Payment	Some differences exist between "conventional" lead users (unpaid developers) and "embedded" lead users (paid developers).	(4) Incentive schemes work partly differently for paid and unpaid developers; paid developers show greater emphasis of status-maintaining and should therefore stimulated by status signals.

could include more instruments to control for endogeneity. Finally, while our results are drawn from a sample of developers in mobile phone (Ye and Kankanhalli, 2018) and social network platforms, with the rise of platforms for industrial applications and industrial Internet of Things (IoT), new types of platform-developer relations might emerge (Gawer and Cusumano, 2014), which require confirmation of our findings.

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Appendix

Table A-1 presents the measurement instrument used in the online survey.

Table A-1. Measurement Instrument

Lead userness (adapted from Schweisfurth and Raasch, 2015)	**Loadings**
1. While using apps, I am often confronted with problems that cannot be solved by apps available on the market.	.78
2. In the past, as an app user I have had problems with features of some of my apps that could not be solved with conventional app offerings.	.65
3. In my opinion, there are still unresolved problems with apps.	.63

4. I have needs related to apps that are not covered by the products currently offered on the market.	.75
5. I often get irritated by the lack of sophistication in certain parts of apps.	.60
6. (*) How many apps do you use actively (score after z-transformation)?	.35
Expected positive performance outcomes (adapted from Yuan and Woodman, 2010)	
1. The more innovative I am, the better my performance.	.66
2. Coming up with creative ideas helps me do well on projects.	.78
3. The project will perform better if I often suggest new ways to achieve objectives.	.71
Reputation as innovative (adapted from Yuan and Woodman, 2010)	
1. People come to me when they want new ideas.	.74
2. Others in the project often expect me to contribute innovative ideas.	.81
Innovative work behavior (Scott and Bruce, 1994)	
1. In app development, I search out new technologies, processes, techniques, and/or product ideas.	.63
2. In app development, I generate creative ideas.	.81
3. In app development, I am innovative.	.79
(Control variable) Job satisfaction (adapted from Morris and Venkatesh, 2010)	
1. Overall, I am satisfied with programming my apps.	.86
2. I am satisfied with the important aspects of my app development.	.89
Note: (*) item LU6 was removed due the low loading.	

Table A-2 presents the cross-loadings of the constructs of our model.

Table A-2. Cross-loadings

	Lead userness	EPPO	RAI	IWB	Job satisfaction
LU1	0.798				
LU1	0.733				
LU3	0.724				
LU4	0.754				
LU5	0.697				
EPPO1		0.857			
EPPO2		0.639			
EPPO3		0.709			
RAI1			0.830		
RAI2			0.754		
IWB1				0.759	
IWB2				0.745	
IWB3				0.816	
JS1					0.877
JS2					0.828

Note: Varimax rotation, loadings below 0.4 not displayed. This table reports the loadings after removing LU6.