Perceived Software Platform Openness: The Scale and its Impact on Developer Satisfaction

Completed Research Paper

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Abstract

Application developers are of growing importance to ensure that software platforms (e.g. Facebook, Android) gain or maintain a competitive edge. However, despite calls for research to investigate developers' perspective on platform-centric ecosystems, no research study has been dedicated to identifying the facets that constitute developers' perception of platform openness. In this paper, we develop a scale of platform openness as perceived by third-party application developers. Using both qualitative and quantitative methods, we conceptualize perceived platform openness as a second-order construct. Empirical evidence from a survey of Android application developers (N=254) support this construct's validity. Furthermore, we identify perceived platform openness as a major driver of complementors' overall satisfaction with the platform. Our study thus contributes to a better understanding of platform openness in particular and the management of platform-centric ecosystems in general.

Keywords: Perceived platform openness, scale development, software-based platforms, platform-centric ecosystems, platform management, third-party developers, Android applications.

Introduction

Platform-centric ecosystems are emerging as a dominant organizational model in the software industry (Cusumano 2010). Regardless of whether the focus is on ERP software, smartphones or videogames, the essential management challenge is to establish and maintain a successful software platform. The importance of software platforms became particularly obvious in the smartphone sector. The previously dominant Symbian platform's market share eroded significantly due to the emergence of a new generation of software platforms such as Google's Android OS or Apple's iOS (Gartner 2010). These new platforms' overwhelming success cannot, however, solely be attributed to the hardware's superior quality or its built-in features, but may also be ascribed to the software platforms' attractiveness to application developers. By establishing open software platforms that allow third-party developers to create applications and distribute them over the platforms' built-in marketplaces, Google and Apple both managed to create prospering ecosystems around their smartphone operating systems. Consequently, Apple's *iOS App Store* and Google's *Android Marketplace* already had 350,000 apps (iOS) and 280,000 apps (Android) available at the beginning of 2011, while, with only 50,000 available applications, Symbian's *OVI Store* fell far short (AndroidLib 2011; Apple 2011; Distimo 2011).

Platform concepts have been discussed in many research disciplines. Consolidating findings from marketing, software-engineering, economics, information systems, and industrial organization, Tiwana et al. (2010) define *software-based platforms* 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"* (p. 675). In this context, the provider of a platform, together with third-party developers of complementary modules (or applications), and end-users, forms a *platform ecosystem* (Cusumano and Gawer 2002). This ecosystem is typically characterized by indirect network effects: On the one side, a software-based platform product's attractiveness for end-users is strongly correlated to the availability of complementary applications. On the other side, third-party developers (whom we refer to here as *complementors*) are only willing to produce complementary applications if a platform provides an adequate sales potential (Church and Gandal 1993; Rochet and Tirole 2003).

In the light of the growing interest in studying software-based platforms, Tiwana et al. (2010) note that *"governing platforms requires a delicate balance of control by a platform owner and autonomy among independent developers"* (p. 676 f.) and, hence, suggest examining the *"formal and informal mechanisms implemented by a platform owner to encourage desirable behaviors by module developers"* (p. 680). Consequently, as an umbrella term for governance and control-related concepts, platform openness has recently received increasing attention in the ongoing scientific debate on software-based platforms and platform-centric ecosystems (i.e. Boudreau 2010, Eisenmann et al. 2009, Anvaari and Jansen 2010). Another call for research regarding the management of complementors was made by Yoffie and Kwak (2006). They find that a deep understanding of complementors and their individual decision processes is crucial to manage them. Hence, before we can develop strategies with which platform managers can manage complementors effectively, we need to understand how the concept of platform openness is formed in the perception of complementors. However, despite its apparent importance, complementors' perspective has been neglected in approaches that investigate platform openness. In fact, there are as yet no validated measurement instruments for complementors' perception of platform openness.

Given these calls for research and the research gap identified above, this paper aims to contribute to a more sophisticated understanding of complementors' individual perceptions of platform openness and how these perceptions relate to their satisfaction. Hence, our research question is:

> *What are the key facets of third-party developers' perceived platform openness (PPO) and how does openness influence developers' satisfaction with a platform?*

By addressing this question, our study makes several contributions. First, we enhance the existing literature on platform openness by developing a comprehensive conceptual framework for perceived platform openness grounded on theoretical deduction and in-depth qualitative investigations. Building on this framework, we develop and validate a PPO measurement instrument, thus providing a starting point for further research on platform openness's impact. Second, by empirically investigating the relationship between PPO and complementors' satisfaction, we identify PPO as a major driver of complementors' overall satisfaction with a platform. Third, by developing a framework of key facets of PPO, we allow

practitioners and, in particular, platform managers to use our results to optimize their application of openness-related instruments.

The remainder of this paper is structured as follows. The next section develops the theoretical basis of this work by drawing on literature on openness in general and vertical platform openness in particular. We then describe our research methodology for the scale development process and present its results. In the concluding section, we discuss the implications of the results for research and practice and point out the paper's limitations, as well as promising areas for future research.

Theoretical Development

Openness in general and platform openness in particular have been under investigation in various strands of literature. In the next sections, we summarize the relevant prior literature and motivate our specific approach to analyzing platform openness as perceived by complementors. Then, we develop a conceptual framework for PPO as a foundation for scale development.

The Developer Perspective as a Basis for Conceptualizing PPO

Related Work on Platform Openness

The concept of openness has been investigated in several research disciplines so far, with various foci. Besides possibly the most prominent example in personality psychology as one factor of the Big Five - "openness to experience" (e.g. McCrae and John 1992) -, openness has been drawn upon in natural sciences (e.g. Bertalanffy 1950), economics (e.g. Blanchard and Illing 2006), personnel psychology (e.g. Wanberg and Banas 2000; Jablin 1979), and in education science (Hodgkinson-Williams and Gray 2008). Furthermore, finding a solution for the trade-off between openness and control of standards (e.g. in the context of introducing new information technology standards) has a long tradition in the literature on the strategic management of technologies (e.g. Shapiro and Varian 1998; Teece 1986).

Given the abundance of application fields for the concept of openness, an all-embracing definition of it is difficult to find. Providing a first common denominator, Luhmann's systems theory and the corresponding open systems concept can be applied to abstractly define openness as the degree to which a system allows and enables the interaction with its environment (Luhmann 1995). While this definition would generally be transferable to the software platform context, Eisenmann et al. (2009) proposed a more concrete and specific definition of platform openness, stating that a software-based platform should be considered open if the contribution, the development, the usage, and the commercialization is not restricted, or if all existing restrictions are reasonable and equally applied to all participants (Eisenmann et al. 2009). Building on this definition, Eisenmann et al. (2009) distinguish strategies of horizontally and vertically opening a platform. Opening a platform *horizontally* means giving up some control by licensing the platform to competitors or integrating further platform sponsors. Typical management decisions to increase horizontal platform openness are letting additional parties participate in the platforms' commercialization by licensing new platform providers (Cusumano and Gawer 2002) or broadening the sponsorship of the platform by allowing additional parties to participate in the development of the platform core (West 2007). On the other hand, the strategy of opening the platform to third-party developers of complementary applications is referred to as *vertically* opening a platform. Eisenmann et al. (2009) give the assurance of backward-compatibility or the avoidance of exclusivity agreements as general examples for levers of vertical openness. However, coming from our research question on third-party developers' perceptions of openness, we focus on vertical openness as the major instrument to manage complementary contributions, in the following[1].

The problem of finding the right degree of vertical platform openness arises from a fundamental trade-off known as "*diversity vs. control.*" When a platform is inherently dependent on a continuous supply of complementary innovations, such as the previously mentioned new generations of smartphone operating systems, opening a platform vertically to external developers potentially increases the complementary

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[1] The interested reader is referred to Katz and Shapiro (1986), Cusumano et al. (1992), Shapiro and Varian (1998), Farrell and Katz (2000) and Farrell (2007) for research on horizontal platform openness.

innovations' diversity (Chesbrough 2003; von Hippel 2005). However, opening a platform vertically and the resultant loss of control could pose problems for a platform provider in at least two respects. First, the orchestration and coordination of resources become more complex, simply because more players and interests are involved (Almirall and Casadesus-Masanell 2010; Greenstein 1996). Second, by delegating the production of complements to external developers, the platform provider also loses the control over the complementary platform features' agenda and, as a result, also over possible fields of application for the platform. As an example, third-party developers might prefer to offer games, although the platform provider had designed the platform for business applications.

Besides studies on platform openness's regulatory implications (e.g. Hagiu 2006; Economides and Katsamakas 2006) and on openness in platforms' technological architecture (e.g. Schlagwein et al. 2010; Anvaari and Jansen 2010), contributions from the strand of literature on platform strategies have specifically focused on questions of vertical platform openness. Building on findings regarding companies' general technology strategy, Cusumano and Gawer (2002) identified facets of vertical openness (although they do not call them that) as part of their platform leadership levers. West (2003) thereafter introduced the platform openness concept as a continuous degree, contrary to the idea of openness as either completely closed or open. Later, platform openness was considered an instrument to steer external innovation (Boudreau 2010; Boudreau and Lakhani 2009; Eisenmann et al. 2009; Parker and Van Alstyne 2009) and the resulting competitive advantages (Economides and Katsamakas 2006).

Despite this constantly increasing research interest, the only study providing an operationalization of platform openness is by Boudreau (2010), who used two (reflective) indicators to measure the construct: (1) selected platforms' licensing policies, and (2) the availability of complementary reference designs. However, considering the multitude of possible facets of PPO, this operationalization does not meet the requirements of a universally applicable measurement instrument. Furthermore, integrating Boudreau's (2010) measures of vertical platform openness in a nomological network estimated through covariance-based structural equation modeling techniques is restricted as the scale comprises discrete and categorical indicators which violates underlying distributional assumptions. Apart from that, a three-indicator model will always return perfect fit as the model is saturated. While the introduction of equality constraints on the indicator loadings and/or error variances can be used to overcome this problem, such modifications are not consistent with congeneric measurement (Jöreskog 1971). Hence, Boudreau's (2010) measurement instrument is not an adequate starting point for PPO measurement.

Motivation to Investigate Developers' Perspective on Openness

Previous contributions on vertical openness investigated the interdependencies between groups of actors within a platform ecosystem (e.g. Boudreau and Lakhani 2009; Parker and Van Alstyne 2008). This perspective generally involves the assumption that the members of a certain group of actors share the same goals and intentions regarding their platform-related activities. Consequently, it is assumed that any of the platform provider's openness-related stimuli result in the group of complementors reacting uniformly. As such, the complementors' individual motivations that arguably influence their decision processes were neglected. Unlike these previous contributions, we chose to investigate vertical platform openness from complementors' "inside perspective." This approach is motivated by the following two considerations: First, the efficacy of so-called hard-power instruments (Nye 1990), such as financial incentives or threatening consequences, is limited in a platform-centric ecosystem due to the platform provider's high dependency on complementary contributions. Hence, to manage complementors, a paradigm shift is required towards soft power and persuading complementors to consider the common goals and visions. However, this approach requires a deeper understanding of the participating actors, their goals, and decision processes (Yoffie and Kwak 2006). Investigating complementors' perception of openness on an individual level may help gain this understanding.

The second consideration is based on the observation that, owing to the low entry barriers in vertically open platforms (e.g. low upfront costs or publicly available specification and documentation), joining a software platform becomes also possible for less professional complementors (West 2003). Accordingly, the assumption of a homogeneous group of professional complementors sharing the same goals and intentions may not hold true in practice (Hilkert et al. 2010). On the contrary, complementors' assessments of whether a certain openness facet is perceived as limiting largely depend on their individual perceptions. This can be exemplified by the entry fee a complementor has to pay to join a platform (e.g.

$99-$299 per year for the iOS developer program), which could be a facet of openness. On the one hand, a complementor whose primary goal is, for example, to present his or her advanced skills in developing applications might be discouraged by a high entry fee. On the other hand, a mostly business-oriented complementor could appreciate a high entry barrier, since it prevents further competition (Boudreau 2010). Accordingly, we argue that investigating platform openness on the individual complementors' level will allow a better explanation of platform openness perception and its subsequent impact on individual decisions of complementors.

A Framework for Perceived Platform Openness (PPO)

Following Rossiter's (2002) recommendations on conceptualizing constructs, we consider the attribute of interest (i.e. degree of openness), the focal object (i.e. software platforms), and the rater entity (i.e. complementary application developers) to define perceived platform openness (PPO):

> *Perceived platform openness (PPO) is a software-based platform's degree of openness as perceived by its complementary application developers.*

Based on this definition and as a conceptual foundation for scale development, we subsequently develop a theoretical framework for PPO's sub dimensions by further specifying the degree of openness on software platforms (Bollen 2011; Rossiter 2002).

As the term "degree of openness" already indicates, our understanding of openness is based on West's (2003) idea that a technology or platform is mostly neither completely open nor completely closed, but somewhere in between these two extreme points. Building on West's previous work, West and O'Mahony (2008) have identified *transparency* and *accessibility* as openness's two constitutive dimensions in the software ecosystem context. Following this notion, we define openness' *transparency* dimension as the extent to which it allows (current and potential) complementors to fully understand how to create and distribute third-party applications, as well as to comprehend and follow all platform-related governance decisions. *Accessibility* is defined as the degree to which a software platform allows complementors to contribute to it by creating and distributing third-party applications without having to face any platform-specific restrictions. At this point, it should be noted that transparency and accessibility should be considered as conceptually distinct dimensions of openness, since a software platform could well be very transparent without allowing externals to contribute, or vice versa. However, a platform can only be considered completely open if it is fully transparent and fully accessible. In summary, the two dimensions *transparency and accessibility* are considered the two forming antecedents of openness.

Software platforms can also be subdivided into two subcomponents. Consistent with the interdisciplinary idea of information systems research, software platforms are *"simultaneously social and physical artifacts"* (Orlikowski and Barley 2001, p. 149; Coy 2004), hence, the *"technical architecture and organizing principles of these platforms jointly determine their evolutionary trajectories"* (Tiwana et al. 2010, p. 676). This distinction can be transferred to the complementor perspective: On the one hand, third-party developers interact with the *technical platform* and, on the other hand, with the platform's marketplace as the major *distribution channel* for complementary applications (Schlagwein et al. 2010). Typical examples are the iTunes App Store for Apple's iOS platform or the Android Marketplace for Android devices. In this regard, the technical platform refers to all facets of the platform related to the technical development of a third-party application which includes, for example, APIs and SDKs, as well as all kinds of conditions and communications (such as documentations, blogs, and forums) related to the technical development. The platform's distribution channel (or marketplace) refers to all facets of application distribution. Besides the design of the marketplace, this sub dimension includes the terms and conditions of participating as well as related communications.

Platforms can be quite open in terms of their technical feasibility while, simultaneously, only certain contents or functionality may be distributed in the corresponding marketplace. Vice versa, platforms that do not restrict access to their distribution channels may still fall short with regard to their technical openness, for example, in terms of their technical interoperability with other platforms. As such, in terms of openness, the technical platform and the distribution channel should be considered conceptually distinct components of software platforms.
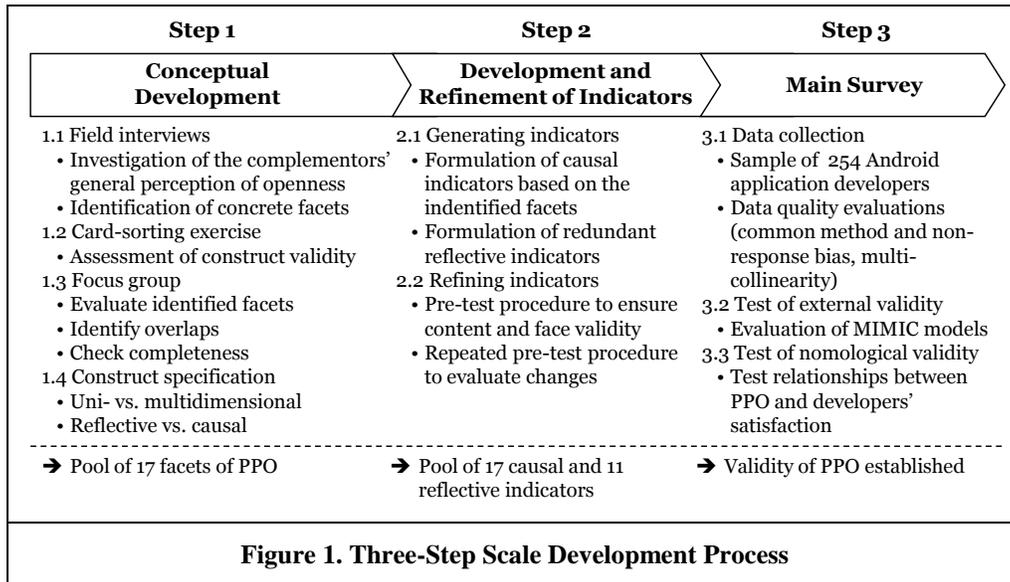
By combining transparency and accessibility as the antecedents of openness, and the technical platform and the distribution channel as a software platform's major components, we derive four sub dimensions of

PPO that comprehensively cover the construct's concept. Hence, the resulting framework for PPO (see Table 1) provides the starting point for the PPO measurement instrument's conceptual development, which is described in the next section.

Table 1. Conceptual Framework for Perceived Platform Openness (PPO)		
	Transparency	**Accessibility**
Technical Platform	*TechTrans* Transparency of the technical platform and related governance processes	*TechAccess* Degree to which the technical platform allows complementors to contribute
Distribution Channel	*DistTrans* Transparency of the associated distribution channel and related governance processes	*DistAccess* Degree to which the associated distribution channel allows the complementors to contribute

Development of the PPO Scale

Recognizing the lack of previous scale development efforts in the vertical platform openness literature, we intended to develop a new PPO scale that captures the most critical facets and provides a robust foundation for examining the consequences of platform openness as perceived by application developers. On the basis of established scale development guidelines (Churchill 1979; DeVellis 2003; Hinkin 1998), we used a systematic three-step process, involving a variety of methods, to develop, refine, and validate the PPO measurement. As shown in Figure 1, the three steps were (1) the conceptual development, (2) the development and refinement of the indicators, and (3) the main survey to validate the instrument. Table 1 in the Appendix shows the research participants' roles and results regarding the development of the PPO measure in the three stages.

Step 1	Step 2	Step 3
Conceptual Development	**Development and Refinement of Indicators**	**Main Survey**

1.1 Field interviews
  • Investigation of the complementors' general perception of openness
  • Identification of concrete facets
1.2 Card-sorting exercise
  • Assessment of construct validity
1.3 Focus group
  • Evaluate identified facets
  • Identify overlaps
  • Check completeness
1.4 Construct specification
  • Uni- vs. multidimensional
  • Reflective vs. causal
	2.1 Generating indicators
	  • Formulation of causal indicators based on the indentified facets
	  • Formulation of redundant reflective indicators
	2.2 Refining indicators
	  • Pre-test procedure to ensure content and face validity
	  • Repeated pre-test procedure to evaluate changes
		3.1 Data collection
		  • Sample of 254 Android application developers
		  • Data quality evaluations (common method and non-response bias, multi-collinearity)
		3.2 Test of external validity
		  • Evaluation of MIMIC models
		3.3 Test of nomological validity
		  • Test relationships between PPO and developers' satisfaction

→ Pool of 17 facets of PPO	→ Pool of 17 causal and 11 reflective indicators	→ Validity of PPO established

Figure 1. Three-Step Scale Development Process

Step 1: Conceptual Development

Building on the theoretical considerations presented in the previous section, the conceptual framework for PPO (see Table 1) helped provide a starting point for conceptualizing PPO. However, the deductive approach did "*not result in easily identifiable dimensions for which items can then be generated*" (Hinkin 1998, p. 107). Accordingly, and in line with the recommendation by Hinkin (1998), an inductive approach was undertaken to conceptualize PPO by means of an exploratory investigation with target raters and expert judges. Therefore, concrete PPO facets were identified, classified, and refined through the use of a comprehensive process, which included exploratory interviews, a card-sorting procedure, and focus group discussions with expert judges and target raters.

Field Interviews, Card-Sorting Exercise, and Focus Group

In line with the recommendations by Rossiter 2011, our qualitative investigations were conducted with the intention of covering the full extent of the complementors' openness perceptions. Hence, we decided to deploy open interviews which should motivate the developers to freely describe their association with the term "platform-openness" and subsequently name concrete facets or restrictions of openness they were aware of (Gläser and Laudel 2006). This approach is especially well-suited for emergent phenomena providing the broadest possible contextual information for assessment and understanding (Flick 2009). The criteria to select our interview partners were led by the idea to reproduce the diversity of all developer types with regard to the organizational background (salaried developer, entrepreneur, hobby developer, etc.) and the type of applications (games, tools, etc.). Furthermore, our sample also included multi-homers, which allowed us to cover the perspective of developers that are familiar with both platforms. The size of our sample was determined by a predefined stop criterion: The interview procedure was repeated until three successive interviews did not reveal any new openness facets, which allowed us to assume information saturation (Rossiter 2002). As a result, a total number of ten third-party application developers were interviewed. The respondents were either software company employees, freelancer, had founded their own companies, or described themselves as "interested amateurs". However, all respondents confirmed to be key informants regarding the development and distribution of complementary applications of their organization.

After transcribing the interviews, we performed an inductive content analytic approach (Krippendorff 2004). During this process, the developers' statements were recursively consolidated and then classified with the four PPO sub dimensions (*TechTrans*, *DistTrans*, *TechAccess*, and *DistAccess*). To evaluate the classification, a Q-Sort-like procedure was performed (Anderson and Gerbing 1991; Hinkin 1998; Kerlinger 1986). For this purpose, another group of six application developers were given a thorough description of the four PPO sub dimensions, along with a set of cards with one of the identified facets and a brief description. The developers were then asked to assign each of the cards either to one of the four sub dimensions or to an "ambiguous" category. During the task, the developers were asked to think aloud and explain each of the card assignments (Strack and Martin 1987). To evaluate our classification, the hit ratio was calculated as the ratio of correct item assignments to the total number of assignments (Hinkin 1998). We noticed that all judges felt comfortable with assigning each of the facets to either the technical platform or the distribution channel (hit ratio = 89%). However, some of the judges had difficulties with the distinction between transparency and accessibility (hit ratio = 68%). By analyzing these developers' qualitative feedback, we found that the problems were mostly due to a wording issue. While we defined accessibility as the degree to which a software platform allows complementors to contribute to the platform (in line with West 2003), the developers, who were mostly technically oriented, thought of accessibility in terms of the degree to which an information system is made accessible to people with disabilities (see, e.g. W3C 2011). To prevent further problems with this issue, we decided to avoid using the term "accessibility" in our measurement items. During this procedure, we also noticed that none of the facets showed a significant number of assignments to the "ambiguous" category, although the facets resulted from open questions without mentioning the existence of openness dimensions. Accordingly, we assume that our four-dimensional concept of PPO does sufficiently cover the diversity of developers' openness perceptions.

After the Q-Sort task, seven experts on software platforms, of whom three were application developers with more than four years of experience in mobile application development for multiple software platforms and four were IS researchers with special expertise in software business, were invited to participate in a focus group (Morgan 1997). The specific goals of this procedure were (1) to evaluate whether all the identified facets are actually facets of openness, (2) to identify possible overlaps between the facets, and (3) to check if the identified facets are sufficiently inclusive and constitute the main PPO components. The results of this procedure revealed that two facets, namely "the platform provider privileges big companies" and "the developers' agreement on the need for certain content restrictions," were found to be a matter of "fairness" (Joshi 1989) rather than actual platform openness facets. Hence, these two facets were excluded from the framework. Furthermore, four facets were excluded because the members of the focus group jointly agreed that these facets were already sufficiently covered by other superordinate facets. For example, "the possibility to derive technical support from other complementors" was excluded because the experts considered this facet to be sufficiently covered by "the platform offers

features to communicate with other complementors." Beyond these issues, all the experts agreed that the remaining pool of facets does cover the main PPO components sufficiently.

The resulting conceptual PPO framework, including the remaining 17 openness facets and their assignment to the four sub dimensions, is depicted in Table 2.

Table 2. Facets of Perceived Platform Openness (PPO)		
	Transparency	**Accessibility**
Technical Platform	▪ Exchange among complementors ▪ Technical documentation ▪ Technical support by provider	▪ Learnability of technical standards ▪ Availability of development tools ▪ Technical interoperability ▪ Functional range ▪ Technical performance ▪ Cost of required technical equipment
Distribution Channel	▪ Communication of content rules ▪ Transparency of terms and conditions ▪ Information on distribution channel ▪ Transparency of market mechanisms ▪ Communication with end-users	▪ Financial entry barriers ▪ Restrictive terms and conditions ▪ Availability of distribution channel

Construct Specification

The construct specification is about identifying the direction of causality between the indicators and the latent variable. Reflective indicators are affected by the underlying unobserved construct and, accordingly, "reflect" the construct (MacCallum and Browne 1993). In contrast, causal indicators are understood as proximal antecedents and cause the construct (Law and Wong 1999)[2]. Owing to this fundamental difference, a possible misspecification could induce both Type I and Type II errors (Jarvis et al. 2003; Petter et al. 2007). In order to avoid the risk of misspecification, the decision rules suggested by Jarvis et al. (2003) were utilized.

Regarding the relationship between PPO and its sub dimensions, we argue that developers could perceive each of the four sub dimensions as open, while the other three sub dimensions are considered closed. Hence, a correlation between these sub dimensions is possible but not necessary. Furthermore, a platform will only be perceived completely open, if all four sub dimensions are considered open. Accordingly, the four sub dimensions are not interchangeable because dropping or adding sub dimensions would change the construct's conceptual idea. For this reason, it can be assumed that the causality flows from the sub dimensions to the construct and that the four sub dimensions are consequently considered causal indicators of PPO (Bollen 2011; Jarvis et al. 2003; Petter et al. 2007).

The same points can be made with regard to the first-order measurement models. Here, each of the identified facets could be perceived as open, while some or all of the other facets are considered closed. Analogically, no overly strong correlations are expected between the openness-related facets. Since complementary developers regard openness as the sum of the mentioned facets, the direction of causality is assumed to flow from the indicators to the sub dimension constructs. Accordingly, the openness-related facets are considered causal indicators of the PPO sub dimensions (Jarvis et al. 2003; Petter et al. 2007; Bollen 2011).

In summary, the resulting construct structure is classified as a causal first-order, causal second-order ("type IV") model (Jarvis et al. 2003).

Step 2: Development and Refinement of Indicators

As we elaborated in the previous section, the theoretical and preliminary empirical investigations allude to the PPO construct having a causal specification. Hence, the procedure proposed for developing reflective indicators, particularly the domain sampling approach of choosing the most suitable subset of indicators

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[2] We refer to Bollen (2011), who distinguishes causal and composite indicators, with composite indicators completely determining the underlying latent variable while causal indicators have no such restriction.

from the universe of theoretically possible indicators (e.g. DeVellis 2003), is not applicable in this case. Conversely, the idea of causal specification is that the selected indicators should preferably cover the construct's entire scope (Petter et al. 2007).

Generating Indicators

In line with this idea of a causal specification, the initial pool of indicators had to be sufficiently inclusive to fully cover the above-described content structure of the PPO construct (Jarvis et al. 2003). Accordingly, based on the identified concrete openness facets, a pool of statements was generated for each of the four openness dimensions. Each of the causal indicators covers one of the openness-related facets identified in the previous step.

As we will elaborate in step 3, we needed to estimate multiple indicators and multiple causes (MIMIC) models in order to evaluate our measurement instrument's external validity. This approach required the development of redundant sets of reflective indicators. Consequently, a set of 11 reflective indicators was developed that tapped into the general perception of *PPO*, *TechTrans*, *DistTrans*, *TechAccess*, and *DistAccess*. For the causal and reflective sets of indicators, conventional guidelines were followed, for example, simple language that is familiar to the target raters (i.e. application developers), preferably short statements, avoidance of ambiguity, and consistency in terms of perspective (Hinkin 1998; Spector 1992). In addition, the term "accessibility" was avoided in the indicators, as the Q-Sort procedure performed earlier had revealed that this term seemed ambiguous to some developers (see step 1). All statements were formulated so that they could be assessed by means of a five-point Likert scale.

Refining Indicators

Subsequently, a first pre-test was undertaken with five application developers and two researchers by means of cognitive interviews (including extensive probing and think-aloud answers) to ensure that all the items were understood as intended (Strack and Martin 1987). As a result, several of the initially generated items were refined to increase their understandability and eliminate possible misunderstanding. The repetition of this pre-test procedure with three other application developers and two researchers revealed no further problems in terms of face and content validity. Table 3 shows a list of the 17 resulting causal indicators; the 11 reflective indicators are reported in Table 2 in the Appendix.

Table 3. Causal Indicators of Perceived Platform Openness (PPO)		
	Transparency	**Accessibility**
Technical Platform	▪ The platform promotes features to communicate and exchange with other application developers (*exchange among complementors*) ▪ The documentation of the technical platform is comprehensible, useful, and complete (*technical documentation*) ▪ The platform offers features to receive technical support from other application developers (*technical support by provider*)	▪ Getting used to the platform's technical standards is easy (*learnability of technical standards*) ▪ The platform offers helpful tools that make the development of applications easier (*availability of development tools*) ▪ Technically, the platform allows interoperability with other systems or platforms (*technical interoperability*) ▪ The functional range of the platform restricts application developers (*functional range*)* ▪ The technical performance of the platform restricts application developers (*technical performance*)* ▪ The specific costs of technical requirements (e.g. hard- and software) are an entry barrier (*cost of required technical equipment*)*

Distribution Channel	▪ The platform provider openly communicates the rules on the content of applications (*communication of rules on content*) ▪ The terms and conditions of the platform's marketplace are transparent (*transparency of terms and conditions*) ▪ The platform provider openly communicates information concerning the marketplace (*information on distribution channel*) ▪ The rise and fall of applications in the marketplace are transparent (*transparency of market mechanisms*) ▪ The platforms marketplace allows and supports communication between application developers and end-users (*communication with end-users*)	▪ The specific costs of selling applications in the platform's marketplace (e.g. membership fees) are an entry barrier (*financial entry barriers*)* ▪ The terms and conditions of the platforms marketplace are restrictive (*restrictive terms and conditions*)* ▪ The availability of the platform's marketplace reduces entry barriers for application developers (*availability of distribution channel*)
* reverse-coded indicators		

Step 3: Main Survey

Following the guidelines on the evaluation of formative scales by Diamantopoulos and Winklhofer (2001) and Petter et al. (2007), the PPO evaluation focuses on testing the external validity and evaluating the construct within a nomological network[3].

Data Collection Procedures and Quality Assessments

An online survey was prepared to collect data for the statistical assessment of the PPO scale. The reflective and causal PPO indicators were therefore included in the survey instrument, along with a few simple control variables on the developers' background and demographics. Furthermore, a four-item satisfaction scale was included to evaluate the PPO's nomological validity drawing from Bhattacherjee (2001) and Spreng and Olshavsky (1993) (see Table 2 in the Appendix). In order to minimize response-set artifacts, the order of the indicators was randomized (Andrews 1984). Prior to the main survey, a pre-test was undertaken with five researchers and five application developers. However, since the PPO indicators had already been intensively pre-tested, only minor changes were necessary to the introductions and control questions.

A personalized invitation to participate in the survey was sent via email to 4 978 Android application developers. The application developers were selected by recording all new Android applications and the respective developer contact information via the Android-Market-API (Google 2011) for a period of three months. This approach ensured that a representative subsample was selected in terms of application attributes, and that only active application developers who could actually evaluate the platform openness were invited. Participation was encouraged by offering a free management report of the results after completion of the study. To further increase the response rate, a follow-up email was sent out to all non-respondents after two weeks.

A total of 343 completed responses was received, yielding a response rate of 6.9%. However, some of these responses had to be excluded from the sample due to missing or inconsistent data[4], leaving us with a final sample size of 254 valid responses. Not surprisingly, 98.8% of the respondents are male. When the survey took place, the developers were on average 34.4 years old, had 12.6 years of experience with software development in general, and 3.3 years of experience with mobile application development.

Although the effective response rate of 5.1% is within the range of studies with comparable settings (e.g. Sheehan 2001), and the comparison of the respondents' descriptives with those of the original target

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[3] Due to the causal specification of PPO, we did not evaluate discriminant and convergent validity as suggested by Bollen (2011) and Petter et al. (2007).

[4] Respondents who ignored similar but reverse coded items at least three times and/or who answered the questionnaire in way below the minimum time it would require to read the questions were considered as not serious and were excluded (Oppenheimer et al. 2009). Furthermore, respondents that were part of an organization but did not confirm to be informed about all aspects of the application development and distribution process were excluded as well, since they could not be considered as "key informants" (Segars and Grover 1998).

sample did not show major differences, a further investigation of a possible non-response bias was undertaken. Utilizing the method suggested by Armstrong and Overton (1977), we found a non-response bias to be unlikely, as a series of chi-square comparisons of the first 25 percent and the late 25 percent of responses that completed the survey after the follow-up reminder showed no significant differences.

Given the single method we had used to collect data, we also conducted Harman's one-factor test (Podsakoff and Organ 1986). We performed an exploratory factor analysis of all the variables, but no single factor was observed and no single factor accounted for a majority of the covariance in the variables. Furthermore, a correlational marker technique was used in which the highest variable from the factor analysis was entered as an additional independent variable (Richardson et al. 2009). This variable did not create a significant change in the variance explained in the dependent variables. Both tests suggest that common method bias is unlikely to have significantly affected our analyses and results.

Owing to the causal specification of PPO and the underlying multiple regression approach, excessive correlations between the causal indicator variables could pose a problem. Hence, the causal indicators' variance inflation factors (VIFs) were evaluated (Diamantopoulos and Winklhofer 2001). In our study, multicollinearity did not prove to be a problem, since the maximum VIF was 2.11, which is far below the conservative cut-off value of 3.33 recommended by Diamantopoulos and Siguaw (2006).

To establish the reflective indicators' reliability and validity, we assessed the psychometric properties of the *reflective* models of PPO, its sub dimensions, and the satisfaction construct (i.e. including only reflectively measured constructs) (Fornell and Larcker 1981). Since the AVEs ranged between .63 and .77 and all indicator loadings were above the threshold value of .70 and significant ($p < 0.001$), convergent validity is assumed. The composite reliability scores ranged between .78 and .92 and thus exceed the threshold value of .70. In addition, all square roots of AVE exceeded inter-construct correlations, providing strong evidence of discriminant validity (see Table 3 in the Appendix).

External Validity Tests

A widely accepted approach to assess the external validity of a causal measurement instrument as a set is to estimate a multiple indicators and multiple causes (MIMIC) model (Hauser and Goldberger 1971; Jöreskog and Goldberger 1975; Diamantopoulos and Winklhofer 2001). The nature of a MIMIC model is that a latent variable is directly caused by its causal indicators and is simultaneously reflected by a set of redundant reflective indicators (Bollen 1989). Given the content validity of the causal and reflective indicators, a MIMIC model's acceptable model fit provides evidence of the instrument's external validity.

The LISREL software (version 8.80; Jöreskog and Sörbom 2006) was utilized for the analysis of the MIMIC structural equation models (SEM), since the underlying estimation approach allows for evaluating a structural equation model's overall fit and is considered highly accurate in terms of parameter estimations (Gefen et al. 2003). The observed variables' correlation matrices were used as input to derive standardized solutions (Jöreskog and Sörbom 1993). Consistent with established recommendations on the evaluation of LISREL estimation results, a number of fit indices were assessed to evaluate the overall model fit. The absolute fit indices include the χ^2/d.f. ratio (Wheaton et al. 1977), the AGFI (adjusted goodness of fit, Jöreskog and Sörbom 1982), and the RMSEA (root mean square error of approximation). However, due to sample size's detrimental effect on these absolute fit indices, more recent contributions recommend relative fit indices, which are less sensitive to sample size (Barrett 2007). Hence, the relative fit indices NFI (normed fit index) and the CFI (comparative fit index) were also considered (Bentler and Bonett 1980; Bentler 1990).

According to the proposed second-order model structure, and in line with previous causal second-order model testing (Barki et al. 2007; Shin and Kim 2011), the evaluation was performed in two subsequent steps: First, the isolated MIMIC models' fit was evaluated in respect of each of the four PPO sub dimensions (see Figure 2). Thereafter, PPO was assessed as an aggregate second-order construct.

Assessment of TechTrans, TechAccess, DistTrans, and DistAccess

The evaluation of the *TechTrans* MIMIC Model with three formative and two reflective indicators showed good fit statistics for all the indices (χ^2=2.58, d.f.=2, AGFI=0.97, RMSEA=0.033, NFI=0.98, CFI=1.00). This indicates that the hypothesized model is a good approximation of the population and supports the

model's stability. As shown in Figure 2a, all three causal indicators proved significant (p < 0.01). Hence, the three facets can be considered relevant causal indicators of the platform's technical transparency.

The MIMIC measurement model for *TechAccess* also resulted in a good model fit (χ^2=9.97, d.f.=5, AGFI=0.93, RMSEA=0.061, NFI=0.97, CFI=0.98). The estimation results indicated that five of the six causal coefficients significantly contribute to the developers' perception of the platform's technical accessibility (see Figure 2b). On the downside, the "cost of required technical equipment" only had a minor impact on TechAccess and did not prove significant and should therefore be considered candidate for removal (Cenfetelli and Bassellier 2009). Indicators should, however, only be eliminated after sound conceptual considerations (Diamantopoulos and Winklhofer 2001). In our case, it can be argued that with regard to the Android application developers, the selected group of raters is unlikely to perceive the required technical equipment's cost as a restriction, because Android applications' development does not require specific hardware or commercial software. However, other software-based platforms do require specific technical equipment (e.g. iOS applications need to be developed on an Apple device). Following Cenfetelli and Bassellier's (2009) recommendation on handling causal indicators' nonsignificant weights, we thus decided to keep this indicator in light of its significant zero-order correlation with the associated construct.

The estimation of the MIMIC measurement model for *DistTrans* produced a good model fit as well. With χ^2=2.11, d.f.=4, AGFI=0.98, RMSEA=0.00, NFI=1.00, and CFI=1.00, all the fit indices were well within the expected range. Hence, the model's stability is supported. The evaluation of the indicators weights shows that all five factors are highly significant causal indicators of *DistTrans* (p < 0.01, see Figure 2c).

Figure 2 (a-d). Isolated MIMIC models (N=254; * p<0.05; ** p<0.01; *** p<0.001)
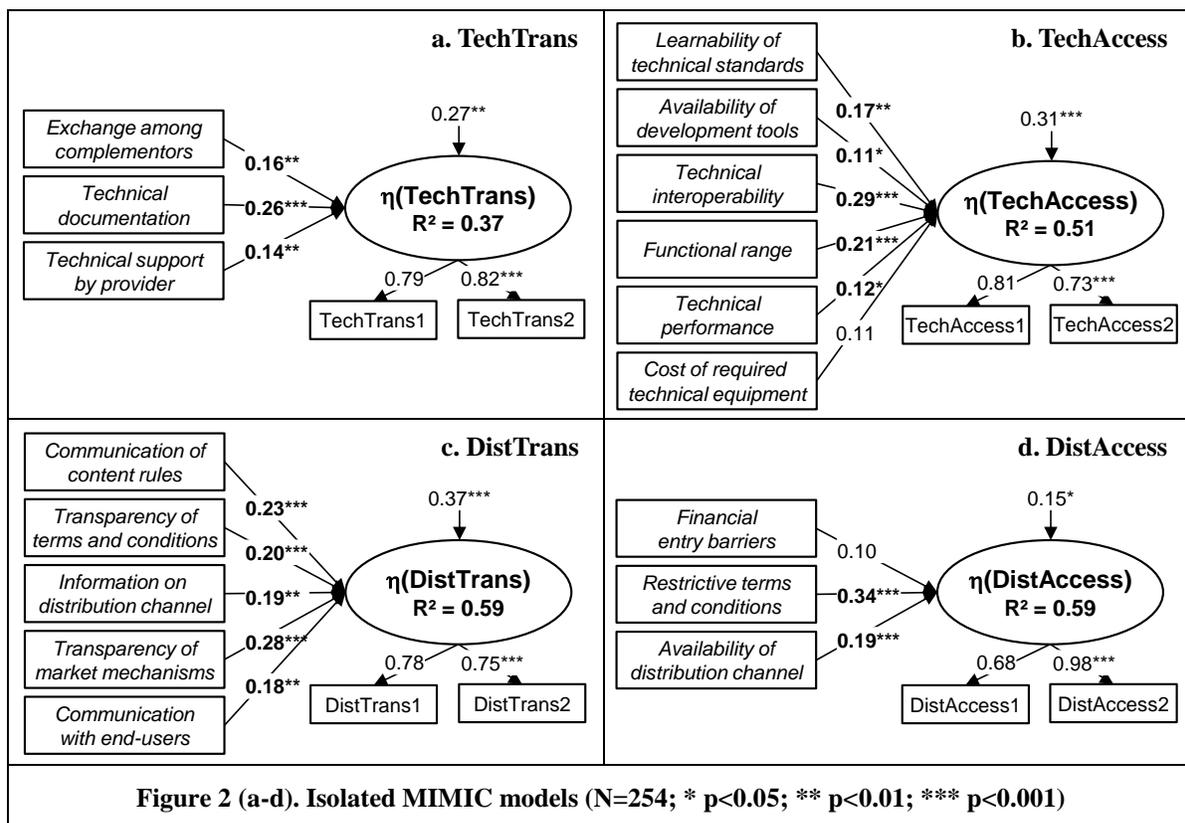
The evaluation of the *DistAccess* MIMIC Model showed good fit statistics (χ^2=1.18, d.f.=2, AGFI=0.99, RMSEA=0.00, NFI=0.99, CFI=1.00), which supports the model's stability. The evaluation of the indicator weights shows that the second and third facets' contributions to DistAccess are highly significant (p < 0.01, see Figure 2d). However, the facet regarding the specific cost of selling applications in the platform's marketplace ("financial entry barriers") did not prove significant. This facet's low impact can be explained by the comparably low costs of publishing Android applications (i.e. a one-off fee of $25). However, analogous to the arguments presented in respect to the TechAccess MIMIC model, the consideration that

other software-based platforms demand significantly higher fees (e.g. $99-$299 per year for the iOS developer program), together with the indicator's content validity, motivated us to keep this indicator (Cenfetelli and Bassellier 2009).

Assessment of PPO as an Aggregate Construct

For the evaluation of PPO as an aggregate construct, a model was estimated with PPO (identified by its reflective indicators) explained by its four sub dimensions and their facets (see Figure 3). The fit parameters showed mixed results. While the χ^2/d.f. ratio of 2.72 (χ^2=570.69 and d.f.=210) and the RMSEA of 0.075 indicate a good model fit (Wheaton et al. 1977; Browne and Cudeck 1993), the value of the AGFI (=0.76) was just slightly below the cut-off value of 0.8 (Jöreskog and Sörbom 1982). However, due to the high model complexity (28 manifest and 5 latent variables) and the comparably low sample size of N=254, the results of the relative fit indices, which are less sensitive to sample size, should be considered. Since the NFI=0.91 and the CFI=0.93 were both above the cut-off value of 0.9 (Bentler and Bonett 1980; Bentler 1990), the aggregate model fits the data well.

As shown in Figure 3, while 15 of the 17 facets of perceived openness proved significant (p < 0.05), the two facets, "cost of required technical equipment" and "financial entry barriers," had only a minor impact as was already the case in the isolated MIMIC models. Regarding TechTrans, TechAccess, DistTrans, and DistAccess – the second-order PPO indicators –, we find that all four sub dimensions proved highly significant (p < 0.01). Together with an explained variance (R^2) of 0.77 for PPO, the model's stability is supported and a high external validity can be assumed regarding the hypothesized construct's conceptual specification. Furthermore, we assume that the external validity is not affected by the sample size, because the fit indices that are sensitive to sample size (χ^2/d.f. ratio and RMSEA) indicate that the data fits the model well (Browne and Cudeck 1993).
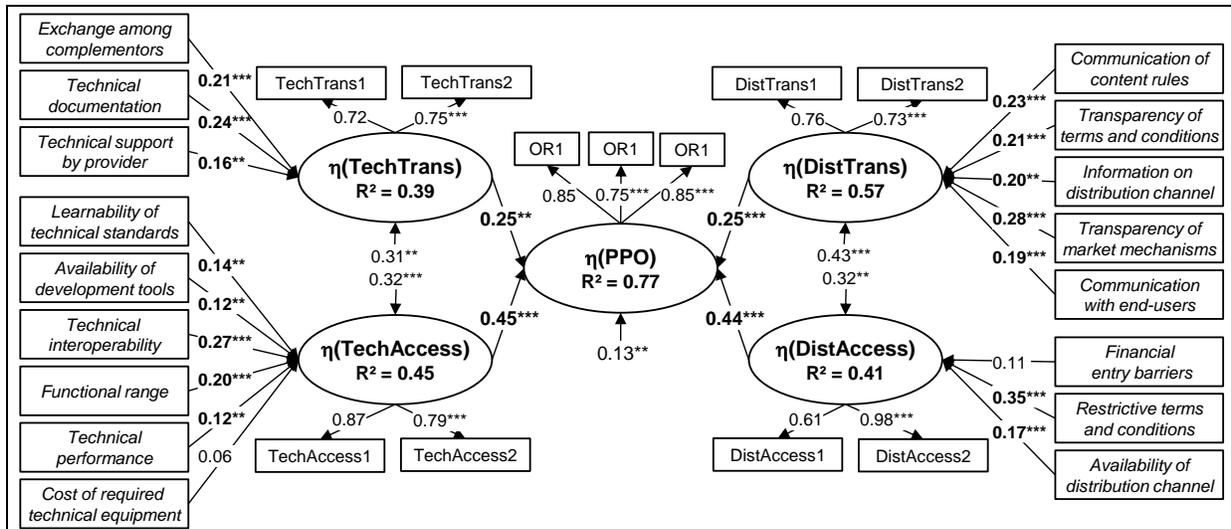

Figure 3. PPO as an Aggregate Construct (N=254; * p<0.05; ** p<0.01; *** p<0.001)

Nomological Validity

Diamantopoulos and Winklhofer (2001) recommend that for the evaluation of the nomological validity, the newly developed construct (PPO) should be related to another construct that (1) is well established and measured by means of reflective indicators and (2) can be considered as antecedent or consequence of the newly developed instrument.

The nomological validity of the PPO construct was assessed by linking PPO to the developers' overall satisfaction with their platform experience. The theoretical consideration of the relationship between perceived openness and satisfaction arises from well-established findings in social psychology. By interpreting the relationship between the platform provider and a developer of complementary applications as a relationship between a superior and a subordinate, a platform's perceived openness can

be considered a special case of superior-subordinate openness (Jablin 1979; Burke and Wilcox 1969). Various studies have confirmed that this type of superior-subordinate openness is a direct cause of the subordinate's job satisfaction (Burke and Wilcox 1969; Jablin 1982; Wanberg and Banas 2000). Transferring these findings to our research context of software-based platforms, we argue that complementors' perceived platform openness should be positively related to their overall satisfaction with the platform. Besides these theoretical considerations, the qualitative feedback from the developers also suggests that a higher level of platform openness should in tendency increase the developers' overall satisfaction. This seems reasonable, because developers might tolerate restrictions of platform openness (e.g. because the platform still provides a predominant revenue potential), but, all else being equal, prefer a platform ecosystem with less restrictions. Accordingly, the relationship between PPO (as an aggregate construct) and overall satisfaction was tested in the nomological model.

Figure 4. Nomological Context: PPO and Satisfaction (N=254; * p<0.05; ** p<0.01; *** p<0.001)
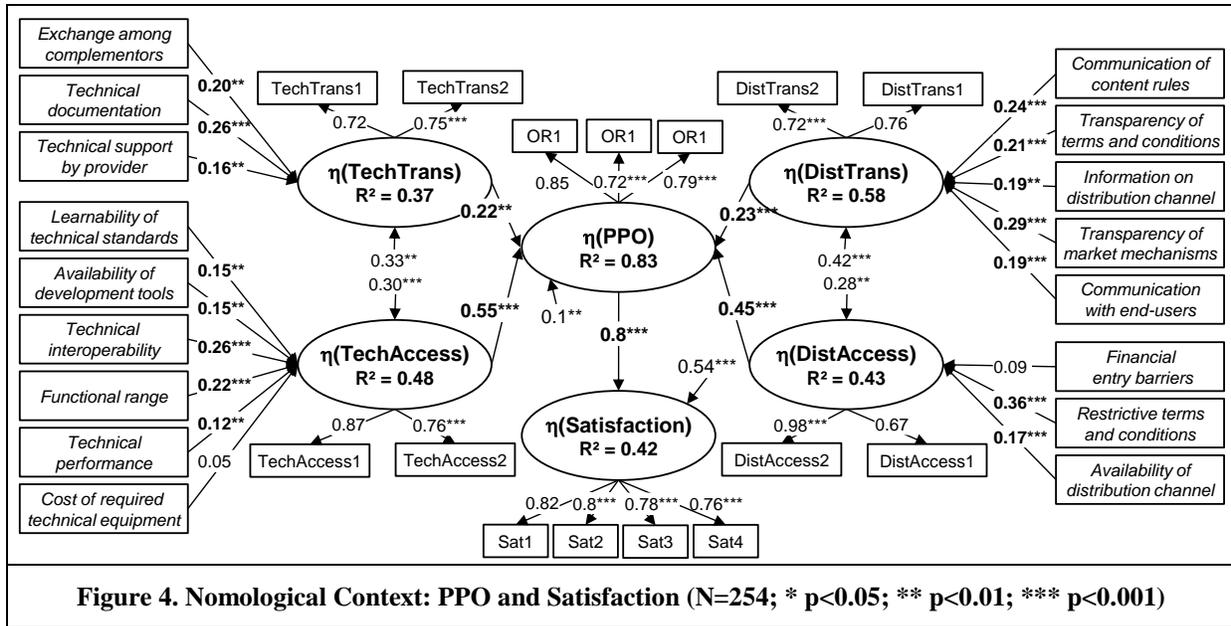
With χ^2=768.04, d.f.=323, AGFI=0.76, RMSEA=0.068, NFI=0.9, and CFI=0.94, the model's overall fit was slightly better than the fit of the MIMIC model for PPO. Furthermore, as reported in Figure 4, all path coefficients within the aggregated PPO construct differed only slightly from the PPO MIMIC model's coefficients, supporting the robustness of our specification.

Regarding the highly significant path coefficient between PPO and satisfaction (β=0.8, p < 0.001), and the ratio of explained variance of satisfaction (R^2=0.42), the hypothesized relationship between the developers' perception of openness and their overall satisfaction with the platform was strongly confirmed. Hence, we conclude that our measure of PPO demonstrates adequate nomological validity.

Discussion

Research and Practical Contributions

Our research provides several relevant insights. First, by indentifying *TechTrans*, *TechAccess*, *DistTrans*, and *DistAccess* as sub dimensions of perceived openness, we provide a comprehensive conceptual PPO framework that allows future research to better understand the platform openness concept and its antecedents. The qualitative investigation showed that the differentiation between transparency and accessibility, and the differentiation between the technical platform and the platform's distribution channel, are relevant distinctions that advance our understanding on key dimensions of perceived platform openness. Second, we developed, refined, and evaluated a comprehensive and fine-grained PPO measurement instrument. Since our instrument was successfully evaluated in terms of content validity, external validity, and nomological validity, it provides a useful starting point for further research on

"platform design and governance" and *"environmental dynamics,"* which Tiwana et al. (2010, p. 678) identified as the two broad sets of research opportunities in the field of software-based platforms.

Beyond these research insights, our study provides relevant practical implications as well. First, in line with previous research, platform openness's importance as strategic lever for managing complementors can be confirmed (Tiwana et al. 2010), since our results clearly indicate that the developers' perception of openness is a highly relevant predictor of their overall satisfaction with the platform (β(PPO) = 0.8, p < 0.001). Second, platform managers should develop a holistic view that integrates the various facets of platform openness. Our empirical results show that all four sub-dimensions proved highly significant antecedents of PPO (p < 0.01). None of them should thus be neglected with regard to managing complementors. Third, the identification of concrete facets of openness and the extent of their relative impact on developers' perceptions and satisfaction help platform managers optimize their application of openness-related instruments. Our results with regard to the Android platform, for example, show that "technical documentation" and "technical interoperability" are the two factors that contribute most to the perception of technical openness. Accordingly, as the Android platform's leading manager, Google may focus its investigations on its technical platform's possible deficits regarding these two facets, as they are the strongest levers for increasing technical openness and, in turn, for increasing the developers' satisfaction with the platform.

Limitations, Further Research, and Conclusion

Our research approach has some limitations. First, our results' external validity is limited to the selected platform, as our main survey's target raters were Android developers. Further research should extend the PPO scope by first transferring the measurement instrument to other smartphone platforms, and subsequently to other software platforms such as social networks or videogames. Beyond helping to further evaluate the measurement instrument, a comparison of the results could provide relevant insights into the openness-related differences between different types of software-based platforms (e.g. B2C vs. B2B platforms).Second, although the tested nomological network of PPO and developer satisfaction does meet the requirements formulated by Diamantopoulos and Winklhofer 2001, the nomological context is limited. Hence, in our further research, we plan to extend this network, for example, by relating the developers' openness perceptions with their individual expectations (expectation confirmation theory, Oliver 1977) and adding additional control variables such as the developers' age, experience, and their individual openness (as a personality trait, McCrae and John 1992). Furthermore, the nomological network could be enhanced by conceptualizing the developers' satisfaction construct in such a way that it captures changes in satisfaction. Third, the selected second-order construct structure was not cross-validated against alternative specifications (e.g. a one-dimensional construct directly caused by all 17 facets). However, the selected specification was chosen due to the theoretical interest in identifying the underlying antecedents of developers' perceptions of openness and was supported by expert opinion (MacKenzie et al. 2005; Roznowski and Hanisch 1990). Hence, although alternative specifications are possible in principle, a cross-validation was not performed and could be investigated in further research (e.g. Barki et al. 2007). Fourth, our research perspective in this contribution is limited to aspects of vertical openness as the levers to manage complementors (Eisenmann et al. 2009). However, since from the perspective of platform providers, horizontal openness is an important management lever as well, investigating horizontal openness should be considered in further research.

In this paper, we drew on previous research on openness and software-based platforms to conceptualize the perceived platform openness (PPO) construct. Through a comprehensive scale development process, we conceptualized, refined, and evaluated a PPO measurement instrument. In doing so, our study's findings contribute to a better understanding of platform openness in particular and platform-centric ecosystems in general and, hence, will hopefully serve as a useful starting point for further research.

References

Almirall, E., and Casadesus-Masanell, R. 2010. "Open Vs. Integrated Innovation: A Model of Discovery and Divergence," Academy of Management Review (35:1), pp. 27-47.

Anderson, J.C., and Gerbing, D.W. 1991. "Predicting the Performance of Measures in a Confirmatory Factor Analysis with a Pretest Assessment of Their Substantive Validities," Journal of Applied Psychology (76:5), pp. 732-740.

Andrews, F.M. 1984. "Construct Validity and Error Components of Survey Measures: A Structural Modeling Approach," Public Opinion Quarterly (48:2), pp. 409-442.

AndroidLib. 2011. "Android Market Statistics." Retrieved 2011-03-10, from http://www.androlib.com/appstats.aspx.

Anvaari, M., and Jansen, S. 2010. "Evaluating Architectural Openness in Mobile Software Platforms," 4th European Conference on Software Architecture (ECSA), Copenhagen, Denmark: ACM, pp. 85-92.

Apple. 2011. "Apple's App Store Downloads Top 10 Billion." Retrieved 2011-08-29, from http://www.apple.com/pr/library/2011/01/22appstore.html.

Armstrong, J.S., and Overton, T.S. 1977. "Estimating Nonresponse Bias in Mail Surveys," Journal of Marketing Research (14:3), pp. 396-402.

Barki, H., Titah, R., and Boffo, C. 2007. "Information System Use-Related Activity: An Expanded Behavioral Conceptualization of Individual-Level Information System Use," Information Systems Research (18:2), June 1, 2007, pp. 173-192.

Barrett, P. 2007. "Structural Equation Modelling: Adjudging Model Fit," Personality and Individual Differences (42:5), pp. 815-824.

Bentler, P.M. 1990. "Comparative Fit Indexes in Structural Models," Psychological Bulletin (107:2), pp. 238-246.

Bentler, P.M., and Bonett, D.G. 1980. "Significance Tests and Goodness of Fit in the Analysis of Covariance Structures," Psychological Bulletin (88:3), pp. 588-606.

Bertalanffy, L.v. 1950. "The Theory of Open Systems in Physics and Biology," Science (111), pp. 23-29.

Bhattacherjee, A. 2001. "Understanding Information Systems Continuance: An Expectation-Confirmation Model," Mis Quarterly (25:3), pp. 351-370.

Blanchard, O., and Illing, G. 2006. "Makroökonomie." München: Pearson Education Deutschland GmbH.

Bollen, K.A. 1989. "Structural Equations with Latent Variables." New York: John Wiley & Sons.

Bollen, K.A. 2011. "Evaluating Effect, Composite, and Causal Indicators in Structural Equation Models," Mis Quarterly (35:2), pp. 1-14.

Boudreau, K. 2010. "Open Platform Strategies and Innovation: Granting Access Vs. Devolving Control," Management Science (56:10), pp. 1849-1872.

Boudreau, K., and Lakhani, K.R. 2009. "How to Manage Outside Innovation," MIT Sloan Management Review (50:4), pp. 68-77.

Browne, M.W., and Cudeck, R. 1993. "Alternative Ways of Assessing Model Fit," in Testing Structural Equation Models, K.A. Bollen and J.S. Long (eds.). Newbury Park: Sage Publications, pp. 136–162.

Burke, R.J., and Wilcox, D.S. 1969. "Effects of Different Patterns and Degrees of Openness in Superior-Subordinate Communication on Subordinate Job Satisfaction," The Academy of Management Journal (12:3), pp. 319-326.

Cenfetelli, R.T., and Bassellier, G. 2009. "Interpretation of Formative Measurement in Information Systems Research," Management Information Systems Quarterly (33:4), pp. 689-708.

Chesbrough, H. 2003. "Open Innovation: The New Imperative for Creating and Profiting from Technology." Boston: HBS Press.

Church, J., and Gandal, N. 1993. "Complementary Network Externalities and Technological Adoption," International journal of industrial organization (11:2), pp. 239-260.

Churchill, G. 1979. "A Paradigm for Developing Better Measures of Marketing Constructs," Journal of Marketing Research (16:1), pp. 64–73.

Coy, W. 2004. "Between the Disciplines," ACM SIGCSE Bulletin (36:2), pp. 7-10.

Cusumano, M.A. 2010. "Technology Strategy and Management: The Evolution of Platform Thinking," Communications of the ACM (53:1), pp. 32-34.

Cusumano, M.A., and Gawer, A. 2002. "The Elements of Platform Leadership," MIT Sloan Management Review (49:2), pp. 27-35.

Cusumano, M.A., Mylonadis, Y., and Rosenbloom, R.S. 1992. "Strategic Maneuvering and Mass-Market Dynamics: The Triumph of Vhs over Beta," The Business History Review (66:1), pp. 51-94.

DeVellis, R.F. 2003. "Scale Development - Theory and Applications." Thousand Oaks: Sage.

Diamantopoulos, A., and Siguaw, J.A. 2006. "Formative Versus Reflective Indicators in Organizational Measure Development: A Comparison and Empirical Illustration," British Journal of Management (17:4), pp. 263-282.

Diamantopoulos, A., and Winklhofer, H.M. 2001. "Index Construction with Formative Indicators: An Alternative to Scale Development.," Journal of Marketing Research (38:2), pp. 269-277.

Distimo. 2011. "Distimo Releases October 2010 Report." Retrieved 2011-08-29, from http://distimo.com/blog/2010_11_distimo-releases-october-2010-report/.

Economides, N., and Katsamakas, E. 2006. "Two-Sided Competition of Proprietary Vs. Open Source Technology Platforms and the Implications for the Software Industry," Management Science (52:7), pp. 1057-1071.

Eisenmann, T.R., Parker, G., and Van Alstyne, M.W. 2009. "Opening Platforms: How When and Why?," in Platforms, Markets and Innovation, A. Gawer (ed.). Cheltenham: Edward Elgar, pp. 131-162.

Farrell, J. 2007. "Should Competition Policy Favor Compatibility?," in Standards and Public Policy, S.M. Greenstein and V. Stango (eds.). Cambridge: Cambridge University Press, pp. 372-388.

Farrell, J., and Katz, M. 2000. "Innovation, Rent Extraction and Integration in System Markets," Journal of Industrial Economy (48:4), pp. 413-432.

Flick, U. 2009. "An Introduction to Qualitative Research." London: Sage Publications Ltd.

Fornell, C., and Larcker, D.F. 1981. "Evaluating Structural Equation Models with Unobservable Variables and Measurement Error," Journal of marketing research (18:1), pp. 39-50.

Gartner. 2010. "Gartner Says Worldwide Mobile Device Sales to End Users Reached 1.6 Billion Units in 2010; Smartphone Sales Grew 72 Percent in 2010." Retrieved 2011-08-29, from http://www.gartner.com/it/page.jsp?id=1543014.

Gefen, D., Karahanna, E., and Straub, D.W. 2003. "Trust and Tam in Online Shopping: An Integrated Model," Mis Quarterly (27:1), pp. 51-90.

Gläser, J., and Laudel, G. 2006. "Experteninterviews Und Qualitative Inhaltsanalyse." Wiesbaden: VS Verlag für Sozialwissenschaften.

Google. 2011. "An Open-Source Api for the Android Market." Retrieved 2011-08-29, from http://code.google.com/p/android-market-api/.

Greenstein, S.M. 1996. "Invisible Hands Versus Invisible Advisors: Coordination Mechanisms in Economic Networks," in Public Networks, Public Objectives, E. Noam and A. Nishuilleabhain (eds.). Amsterdam: Elsevier Science.

Hagiu, A. 2006. "Proprietary Vs. Open Two-Sided Platforms and Social Efficiency," Harvard Business School Strategy Unit Working Paper No. 09-113, pp. 1-42.

Hauser, R.M., and Goldberger, A.S. 1971. "The Treatment of Unobservable Variables in Path Analysis," in Sociological Methodology, H.L. Costner (ed.). San Francisco: Jossey-Bass, pp. 81-117.

Hilkert, D., Benlian, A., and Hess, T. 2010. "Motivational Drivers to Develop Apps for Social Software-Platforms: The Example of Facebook," 16th Americas Conference on Information Systems (AMCIS 2010), Lima, Peru.

Hinkin, T.R. 1998. "A Brief Tutorial on the Development of Measures for Use in Survey Questionnaires," Organizational Research Methods (1:1), January 1, 1998, pp. 104-121.

Hodgkinson-Williams, C., and Gray, E. 2008. "Degrees of Openness: The Emergence of Open Educational Resources at the University of Cape Town," emerge2008, South Africa, pp. 16–18.

Jablin, F.M. 1979. "Superior–Subordinate Communication: The State of the Art," Psychological Bulletin (86:6), pp. 1201-1222.

Jablin, F.M. 1982. "Formal Structural Characteristics of Organizations and Superior-Subordinate Communication," Human Communication Research (8:4), pp. 338-347.

Jarvis, C.B., Mackenzie, S.B., and Podsakoff, S.M. 2003. "A Critical Review of Construct Indicators and Measurement Model Misspecification in Marketing and Consumer Research," Journal of Consumer Research (30:2), pp. 199-218.

Jöreskog, K.G. 1971. "Statistical Analysis of Sets of Congeneric Tests," Psychometrika (36:2), pp. 109-133.

Jöreskog, K.G., and Goldberger, A.S. 1975. "Estimation of a Model with Multiple Indicators and Multiple Causes of a Single Latent Variable," Journal of the American Statistical Association (70:351), pp. 631-639.

Jöreskog, K.G., and Sörbom, D. 1982. "Recent Developments in Structural Equation Modeling," Journal of Marketing Research (19:4), pp. 404-416.

Jöreskog, K.G., and Sörbom, D. 1993. "Lisrel 8: Structural Equation Modeling with the Simplis Command Language." Licolnwood: Scientific Software.

Jöreskog, K.G., and Sörbom, D. 2006. "Lisrel 8.80 ". Chicago: Scientific Software International.

Joshi, K. 1989. "The Measurement of Fairness or Equity Perceptions of Management Information Systems Users," MIS Quarterly (13:3), pp. 343-358.

Katz, M., and Shapiro, C. 1986. "Technological Adoption in the Presence of Network Externalities," Journal of Political Economy (84:4), pp. 822-841.

Kerlinger, F. 1986. "Foundations of Behavioral Research." New York: Holt, Rinehart and Winston.

Krippendorff, K. 2004. "Content Analysis: An Introduction to Its Methodology." Thousand Oaks: Sage Publications.

Law, K.S., and Wong, C.S. 1999. "Multidimensional Constructs M Structural Equation Analysis: An Illustration Using the Job Perception and Job Satisfaction Constructs," Journal of Management (25:2), pp. 143-160.

Luhmann, N. 1995. "Social Systems." Stanford: Stanford University Press.

MacCallum, R.C., and Browne, M.W. 1993. "The Use of Causal Indicators in Covariance Structure Models: Some Practical Issues," Psychological Bulletin (114:3), pp. 533-541.

MacKenzie, S.B., Podsakoff, P.M., and Jarvis, C.B. 2005. "The Problem of Measurement Model Misspecification in Behavioral and Organizational Research and Some Recommended Solutions," Journal of Applied Psychology (90:4), pp. 710-730.

McCrae, R.R., and John, O.P. 1992. "An Introduction to the Five-Factor Model and Its Applications," Journal of Personality (60:2), pp. 175-215.

Morgan, D.L. 1997. "Focus Groups as Qualitative Research." Thousand Oaks: Sage Publications, Inc.

Nye, J.S. 1990. "Soft Power," Foreign Policy (Autumn 1990:80), pp. 153-171.

Oliver, R.L. 1977. "Effect of Expectation and Disconfirmation on Postexposure Product Evaluations: An Alternative Interpretation," Journal of Applied Psychology (62:4), pp. 480-486.

Oppenheimer, D.M., Meyvis, T., and Davidenko, N. 2009. "Instructional Manipulation Checks: Detecting Satisficing to Increase Statistical Power," Journal of Experimental Social Psychology (45:4), pp. 867-872.

Orlikowski, W.J., and Barley, S.R. 2001. "Technology and Institutions: What Can Research on Information Technology and Research on Organizations Learn from Each Other?," Mis Quarterly (25:2), pp. 145-165.

Parker, G., and Van Alstyne, M.W. 2008. "Innovation, Openness, and Platform Control," Tulane University, Freeman School of Business, New Orleans.

Petter, S., Straub, D., and Rai, A. 2007. "Specifying Formative Constructs in Information Systems Research," MIS Quarterly (31:4), pp. 623-656.

Podsakoff, P.M., and Organ, D.W. 1986. "Self-Reports in Organizational Research: Problems and Prospects," Journal of Management (12:4), Winter 1986, pp. 531-544.

Richardson, H.A., Simmering, M.J., and Sturman, M.C. 2009. "A Tale of Three Perspectives," Organizational Research Methods (12:4), October 1, 2009, pp. 762-800.

Rochet, J., and Tirole, J. 2003. "Platform Competition in Two-Sided Markets," Journal of the European Economic Association (1:4), pp. 990-1029.

Rossiter, J.R. 2002. "The C-Oar-Se Procedure for Scale Development in Marketing," International Journal of Research in Marketing (19:4), pp. 305-335.

Rossiter, J.R. 2011. "Measurement for the Social Sciences: The C-Oar-Se Method and Why It Must Replace Psychometrics." Berlin: Springer.

Roznowski, M., and Hanisch, K.A. 1990. "Building Systematic Heterogeneity into Work Attitudes and Behavior Measures," Journal of Vocational Behavior (36:3), pp. 361-375.

Schlagwein, D., Schoder, D., and Fischbach, K. 2010. "Openness of Information Resources - a Framework-Based Comparison of Mobile Platforms," 18th European Conference on Information Systems (ECIS), Pretoria, South Africa, pp. 1-16.

Segars, A.H., and Grover, V. 1998. "Strategic Information Systems Planning Success: An Investigation of the Construct and Its Measurement," MIS Quarterly (22:2), pp. 139-163.

Shapiro, C., and Varian, H.R. 1998. "Information Rules: A Strategic Guide to the Network Economy." Boston: Harvard Business School Press.

Sheehan, K.B. 2001. "E-Mail Survey Response Rates: A Review," Journal of Computer-Mediated Communication (6:2).

Shin, B., and Kim, G. 2011. "Investigating the Reliability of Second-Order Formative Measurement in Information Systems Research," European Journal of Information Systems).

Spector, P.E. 1992. "Summated Rating Scale Construction: An Introduction." Thousand Oaks: Sage Publications.

Spreng, R., and Olshavsky, R. 1993. "A Desires Congruency Model of Consumer Satisfaction," Journal of the Academy of Marketing Science (21:3), pp. 169-177.

Strack, F., and Martin, L.L. 1987. "Thinking, Judging, and Communicating: A Process Account of Context Effects in Attitude Surveys," in Social Information Processing and Survey Methodology, H.J. Hippler, N. Schwarz and S. Sudman (eds.). New York: Springer, pp. 123-148.

Teece, D.J. 1986. "Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy," Research Policy (15:6), pp. 285-305.

Tiwana, A., Konsynski, B., and Bush, A.A. 2010. "Research Commentary: Platform Evolution: Coevolution of Platform Architecture, Governance, and Environmental Dynamics," Information Systems Research (21:4), December 1, 2010, pp. 675-687.

von Hippel, E. 2005. "Democratizing Innovation." Camebridge: MIT Press.

W3C. 2011. "Web Accessibility Initiative (Wai)." Retrieved 2011-08-29, from http://www.w3.org/WAI/.

Wanberg, C.R., and Banas, J.T. 2000. "Predictors and Outcomes of Openness to Changes in a Reorganizing Workplace," Journal of Applied Psychology (85:1), pp. 132-142.

West, J. 2003. "How Open Is Open Enough? Melding Proprietary and Open Source Platform Strategies," Research Policy (32:7), pp. 1259-1285.

West, J. 2007. "The Economic Realities of Open Standards: Black, White and Many Shades of Gray," in Standards and Public Policy, S. Greenstein and V. Stango (eds.). Cambridge: Cambridge University Press, pp. 87-122.

West, J., and O'Mahony, S. 2008. "The Role of Participation Architecture in Growing Sponsored Open Source Communities," Industry & Innovation (15:2), pp. 145-168.

Wheaton, B., Muthen, B., Alwin, D.F., and Summers, G.F. 1977. "Assessing Reliability and Stability in Panel Models," Sociological Methodology (8:1), pp. 84-136.

Yoffie, D.B., and Kwak, M. 2006. "With Friends Like These: The Art of Managing Complementors," Harvard Business Review (84:9), pp. 88-98.

Appendix

Table 1. Roles of Research Participants				
Steps	**Participants**	**N**	**Activities/Roles**	**Results**
Exploratory Interviews	Complementors*	10	Open-ended exploratory interviews; investigation of the complementors' general perception of openness and identification of concrete facets of openness	"Saturated" list of 23 openness-related facets
Q-Sort Procedure	Complementors*	6	Assessment of content validity; evaluation of the classification	Identification of wording issues
Focus group discussion	Experts**	7	Assessment of content validity	Exclusion of 6 facets due to redundancy or wrong assignment; 17 facets remaining
Pre-Test Round 1	Complementors* and researchers	7	Cognitive interviews (think aloud answers) to ensure face and content validity of PPO indicators and avoid misunderstandings	11 out of 17 indicators reworded
Pre-Test Round 2	Complementors* and researchers	5	Repetition of the pre-test to evaluate the improvements	Face and content validity of the 17 PPO indicators supported
Main Study	Android developers	254	Response to the final survey instrument including all PPO indicators	254 valid responses

* Developers of complementary applications for the iOS and Android platforms.
** Developers with 4 years or more experience and researchers with subject expertise

Table 2. Reflective Indicators	
Perceived Platform Openness (PPO)	**Satisfaction**
▪ The platform restricts application developers (*OR1*)* ▪ The platform is open to application developers (*OR2*) ▪ The platform supports the participation and contribution of application developers (*OR3*)	How do you feel about your overall experience of using the platform? ▪ Very dissatisfied / Very satisfied (*Sat1*) ▪ Very displeased / Very pleased (*Sat2*) ▪ Very frustrated / Very contented (*Sat3*) ▪ Absolutely terrible / Absolutely delighted (*Sat4*)

	Transparency	**Accessibility**
Technical Platform	▪ Application developers can easily understand the technical process of creating an application (*TechTrans1*) ▪ Governance decisions concerning the technical platform are easy to understand and follow (*TechTrans2*)	▪ The technical design and organization of the technical platform support application developers (TechAccess1) ▪ The technical platform restricts the participation of application developers (TechAccess2)*
Distribution Channel	▪ The platform's marketplace is transparent (DistTrans1) ▪ Governance decisions concerning the platform's marketplace are easy to follow and understand (*DistTrans2*)	▪ The design and organization of the platform's marketplace support the distribution and selling of applications (DistAccess1) ▪ The platform's marketplace restricts the participation of application developers (DistAccess2)*

* reverse-coded indicators

Table 3. Reliability and Validity of Reflective Measurement Models					
	factor loadings*	**AVE**	**composite reliability**	**sqrt(AVE)**	**max. inter-construct correlation**
TechTrans	.789, .806	.636	.778	.798	.568
TechAccess	.812, .844	.686	.813	.828	.568
DistTrans	.876, .883	.773	.872	.879	.496
DistAccess	.769, .824	.635	.776	.797	.572
PPO	.791 - .828	.658	.852	.811	.572
Satisfaction	.839 - .870	.729	.915	.854	.528

* $p < 0.001$ for all factor loadings