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Mining the hidden seam of proximity m-payment adoption: A hybrid PLS-artificial neural network analytical approach
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Mining the Hidden Seam of Proximity M-Payment Adoption: A Hybrid PLS-Artificial Neural Network Analytical Approach

Abstract

This study investigates the adoption of proximity mobile payment services (PMPS) using, for the first time, an extended version of the decomposed theory of planned behaviour (DTPB) and considering both the linear and non-linear relationships depicted in the proposed model. Based on a two-stage hybrid analytic methodology, the proposed model was validated empirically using a sample of 951 participants. First, partial least squares (PLS) regression was used to identify the significant drivers of PMPS acceptance predictors. Artificial neural networks (ANN) were then used to rank the relative influence of the significant adoption drivers obtained in the previous step. The PLS results indicate that the extended DTPB provides a solid theoretical framework for studying the adoption of PMPS. The results of the PLS-ANN sensitivity analysis confirmed the PLS results regarding the importance of the determinants' of normative and controlling customers' beliefs, although there were some contradictions concerning the determination of customer attitudes and behavioural intentions towards PMPS usage. The results are discussed and implications are offered.

Keywords: Proximity mobile payment, NFC, Decomposed TPB, Perceived risk, Consumer behaviour; Marketing of high-tech m-services

Mobile phone technologies are growing rapidly and are now fully integrated into the lives of mobile phone users (Wong et al., 2016), playing a critical role in the development of their personal and professional activities (Oliveira et al., 2016; Magsamen-Conrad & Dillon, 2020). Mobile commerce (m-commerce), in particular, has changed the business landscape, offering opportunities to exploit the innovative features of smartphones, tablets and wearables. Among existing m-commerce applications, mobile payment (m-payment) is considered the most important (Dahlberg et al., 2015; Oliveira et al., 2016) as it enables consumers to complete convenient and speedy transactions (Slade et al., 2013) and simultaneously allows merchants to increase sales, reduce transaction costs and achieve high levels of customer loyalty (Karimi & Liu, 2020). Liébana-Cabanillas et al. (2017) indicate two main categories of m-payment systems: remote mobile payment systems (RMPS) and proximity mobile payment systems (PMPS). The latter, depending on the proximity technology used, can be further classified as either near-field communication (NFC)-enabled or Bluetooth low energy (BLE)-enabled PMPS. The PMPS sector is a market that faces growing interest and bright prospects; according to Transparency Market Research (2017), the global PMPS market is expected to rise to \$411.4 billion by 2022. Furthermore, the COVID-19 pandemic has led many developed countries to introduce disincentives to use cash, which is expected to lead to the further use of PMPS in the near future. However, while the finance industry has been an early adopter of the new technology and despite promising predictions (Wang et al., 2017; Del Gaudio et al., 2020), the PMPS market has not evolved accordingly (Johnson et al., 2018), particularly in developed nations (Gerpott & Meinert, 2017). This is causing concern among providers, who are struggling to determine appropriate marketing strategies for improving adoption rates.

This inconsistency calls for further investigation of the factors affecting the adoption of PMPS, particularly considering that the extant literature has not received unreserved

acceptance (Del Bosque & Crespo, 2011). Specifically, some of the existing studies on PMPS adoption are based on various extensions of the technology acceptance model (TAM; e.g. Shaw, 2014; Luna et al., 2019), while others are based on variations of the unified theory of acceptance and use of technology (UTAUT; e.g. Khalilzadeh et al., 2017; Lee et al., 2019).

Given this, and as consumers' intentions to adopt PMPS remain unclear, the current study aims to offer further evidence of the effect of innovation/technology-, normative- and behavioural control-related factors and of innovation risk regarding consumers' intentions to adopt PMPS. The present study is the first to introduce an extension of the decomposed theory of planned behaviour (DTPB) to better identify the determinants of consumers' intentions in the context of adopting PMPS. Our model employs three well-established theoretical innovation acceptance models, namely, the theory of planned behaviour (TPB; Ajzen, 1991), the TAM (Davis et al., 1989) and innovation diffusion theory (IDT; Rogers, 1995), and follows several previous studies that have asserted the superiority of the DTPB over the TAM, IDT and TPB as a model to explain innovation adoption (e.g. Püschel et al., 2010; Taylor & Todd, 1995; Lin, 2007; Huh et al., 2009; Giovanis et al., 2019).

Literature Review

The mobile innovation adoption process has been widely researched in the extant literature (e.g. Song, 2014) with PMPS platforms having recently become the focus. Various theoretical approaches have been used to investigate the process that prospective customers follow before adopting PMPS. This study focuses on the widely accepted NFC-enabled PMPS (Gerpott & Meinert, 2017) that dominate the global PMPS sector and account for 75.3% of a market that is expected to reach a projected \$360.9 billion by 2022. Table 1 presents the most relevant studies in the field of NFC-enabled PMPS adoption and indicates that the majority have relied on various extensions of the TAM (Davis et al., 1989) and TAM2 (Venkatesh & Davis, 2000).

--- Table 1 about here ---

As shown in Table 1, several factors influence customers' intentions to use PMPS. The meta-analysis study conducted by Liu et al. (2019) can be used to group the most significant adoption factors into four categories: technology-related characteristics, consumers' normative factors, consumers' personal factors that facilitate PMPS acceptance, and factors expressing perceived risks and security threats that hinder PMPS adoption.

In several studies, technology-related characteristics, including perceived usefulness and user-friendliness (e.g. Leong et al., 2013; Shaw, 2014; Shin & Lee, 2014; Dutot, 2015; Ooi & Tan, 2016; Ozturk, 2016; Luna et al., 2017; Liébana-Cabanillas et al., 2017; Niemand et al., 2020; Sharma et al., 2019; Zhao et al., 2019) and compatibility with the user's needs and values (e.g. Moroni et al., 2015; Pham & Ho, 2015; Oliveira et al., 2016), have been postulated as being among the main determinants of individuals' attitudes towards PMPS and their willingness to use them. Furthermore, the majority of studies using the TAM/TAM2 as their theoretical base have empirically validated the significant impact of social influence/subjective norms on the adoption of PMPS. For example, Tan et al. (2014), Luna et al. (2017), Liébana-Cabanillas et al. (2017) and Khalilzadeh et al. (2017), posited that normative factors are of paramount importance to consumers' intentions to use PMPS. Finally, several studies have acknowledged the importance of identifying the factors hindering PMPS adoption. Pham and Ho (2015), Ozturk (2016), Su et al. (2017) and Zhao et al. (2019) found that perceived risks/security threats have a significant negative effect, both directly and indirectly, on consumers' willingness to adopt PMPS. Despite the validity and reliability of the TAM and its extensions for modelling the innovation adoption process, it has attracted criticism regarding its effectiveness, largely because it only includes consumers' beliefs about two innovation-related attributes (usefulness and easiness); no other determining factors that influence consumers' willingness to adopt are investigated (e.g.

Venkatesh et al., 2003; Slade et al., 2015a). Moreover, the social norms used to extend this particular theoretical framework mainly use personal information from primary and secondary reference groups and do not consider sources of non-personal information that are thought to contribute to the formulation of subjective norms towards PMPS adoption intentions.

Other studies have used the UTAUT (Venkatesh et al., 2003) and UTAUT2 (Venkatesh et al., 2012), which are a synthesis of eight distinct theoretical models based on sociological and psychological theories to explain human behaviour (e.g. Tang et al., 2014; Slade et al., 2015a; Morosan & DeFranco, 2016; Oliveira et al., 2016; Lee et al., 2019) and includes IDT, theory of reasoned action (TRA), TPB, motivation theory, social cognitive theory, the TPB and TAM hybrid model, and the original TAM and Model of Personal Computer Utilisation (MPCU) . Concerning the UTAUT, perceived user-friendliness and usefulness were incorporated into the model using expectancy factors related to effort and performance along with two other constructs: social influence and facilitating conditions. The UTAUT has predominantly been used to describe potential users' technology adoption behaviour in the organisational context (Slade et al., 2015a); thus, an extended version was introduced, the UTAUT2 model, which encompasses individual perspectives such as hedonic motivation, price value and habits. However, as outlined in Table 1, the influence of the UTAUT2's additional constructs on potential customers' intentions to adopt PMPS has not been confirmed. Moreover, as in TAM/TAM2-related studies, the UTAUT framework does not consider the effects of non-personal communication sources on the determination of subjective norms, or the effects of facilitating conditions (a personal factor) on behavioural intentions or use of innovations (Tang et al., 2014; Slade et al., 2015a, 2015b).

While most studies included in Table 1 considered the role of attitudinal, normative and uncertain factors in modelling potential consumers' intentions to adopt PMPS, none

acknowledged the role of perceived behavioural control (Ajzen, 1991). According to TPB, if potential PMPS consumers believe that they have limited or no control over the performance of the innovation due to insufficient resources, they will not adopt an innovation, regardless positive attitude and favourable subjective norms (Ajzen, 1991). In the context of PMPS, some studies (e.g., Shaw, 2014; Ozturk, 2016; Sharma et al., 2019) have investigated the effects of self-efficacy, a component of perceived behavioural control (Taylor & Todd, 1995), on the perceived user-friendliness of PMPS. Additionally, Slade et al. (2015a) and Lee et al. (2019) considered the effects of facilitating conditions, another component of perceived behavioural control (Taylor & Todd, 1995), on behavioural intentions; however, none of these studies specifically incorporated perceived behavioural control into their models.

Although several models have been used to investigate the adoption of PMPS, none have gained broad acceptance. The present study proposes the DTPB, which has not been used in the context of PMPS thus far, to analyse the factors that determine consumers' intentions to adopt PMPS. This model has been chosen because 1) it incorporates three well-established theoretical innovation acceptance models: the TPB (Ajzen, 1991), TAM (Davis et al., 1989) and IDT (Rogers, 1995); 2) several studies have empirically validated its performance superiority over the TAM, IDT, UTAUT and TPB in the setting of technology-based services adoption and usage (e.g. Taylor & Todd, 1995; Lin, 2007; Huh et al., 2009; Giovanis et al., 2019); 3) based on the aforementioned literature review on PMPS adoption, potential consumers' attitudinal, normative and behavioural control beliefs, which are the main determinants of behavioural intentions under the DTPB framework, are among the most critical factors impacting consumers' decision-making and 4) the DTPB specifically considers the roles of personal and non-personal communication effectiveness and perceived behavioural control to better model potential PMPS consumers' behaviour. This study suggests that the DTPB should include the extension of perceived risk, considering that risk-

related factors are expected to significantly influence the adoption of a financial service such as PMPS (Slade et al., 2015a).

Conceptual Framework and Research Hypotheses

Based on social psychology theory and the PMPS literature, an extended version of the DTPB is proposed to predict the behaviour of potential consumers towards PMPS usage.

The DTPB

This section describes the DTPB and the integration of elements from the TRB, TAM and IDT theoretical frameworks to model potential customers' intentions to use PMPS. This DTPB is based on the TPB (Fishbein & Ajzen, 1975), which assumes that an individual's intentions to act are affected by their attitude (feelings towards performing the target behaviour), subjective norms (the perception that most people or external entities should or should not perform a certain behaviour) and perceived behavioural control (perceptions of internal and external constraints on behaviour). These causal relationships have been empirically validated in the fields of PMPS and RMPS (e.g. Schierz et al., 2010; Slade et al., 2015b; Luna et al., 2017, 2019; Khalilzadeh et al., 2017; Liébana-Cabanillas et al., 2013, 2014, 2015, 2017, 2018b; Liu et al., 2019), e-commerce (Lin, 2007; Kim et al., 2009; Del Bosque & Crespo, 2011), e-services and m-services (Bhattacharjee, 2000; Pedersen, 2005) and e/m-banking (Tan & Teo, 2000; Püschel et al., 2010). Based on the above, the following hypotheses are proposed:

H1a. Consumers' attitudes towards PMPS directly and positively affect behavioural intentions.

H1b. Consumers' subjective norms regarding PMPS directly and positively affect behavioural intentions.

H1c. Consumers' perceived behavioural control regarding PMPS directly and positively affects behavioural intentions.

The DTPB extends the TPB by decomposing individuals' attitudes, subjective norms and perceived behavioural control. According to Taylor and Todd (1995), attitudinal, normative and behavioural control beliefs can be organised into multidimensional constructs. Based on the TAM (Davis et al., 1989) and IDT (Rogers, 1995), the DTPB suggests that attitude is determined by three technology-related attributes: relative advantage, complexity and perceived compatibility (Taylor & Todd, 1995; Tan & Teo, 2000). Relative advantage expresses the degree to which a new technology provides greater benefits than its predecessor. Cost, efficiency, convenience, image enhancement and satisfaction are among the benefits customers consider when assessing the degree of an innovation's superiority to their previous options (Tan & Teo, 2000). Complexity refers to the degree to which an innovation is perceived to be difficult to understand and use (Tan & Teo, 2000). Studies have found that the relative advantage and complexity constructs are similar to the constructs used in the TAM: perceived usefulness and perceived ease of use, respectively. This suggests that the TAM and IDT confirm each other's findings, which enhances confidence in the validity and reliability of these approaches (Lin, 2007).

Perceived usefulness expresses the degree to which 'a person believes that using the system will enhance his or her performance', and perceived ease of use is the degree to which 'a person believes that using the system will be free of effort' (Venkatesh & Davis, 2000, p. 187). The roles of perceived usefulness and perceived ease of use in consumers' attitudes towards using PMPS have been supported by previous studies, despite some contradictory evidence. Several studies (e.g., Liébana-Cabanillas et al., 2015, 2017, 2018a; Luna et al., 2017, 2019) have validated the effect of perceived usefulness on attitude but have failed to show a significant link between perceived ease of use and attitude. However, other studies in the context of financial m-services (e.g. Liébana-Cabanillas et al., 2013, 2014, 2018b; Muñoz-Leiva, 2017; Liu et al., 2019) and m-banking (e.g. Püschel et al., 2010) have

confirmed the positive impact of both perceived ease of use and perceived usefulness on attitude.

Perceived compatibility refers to ‘the degree to which an innovation is perceived as being consistent with existing values, past experiences and needs of the potential adopter’ (Rogers, 1995, p. 223). According to IDT (Rogers, 1995), the likelihood of a potential customer adopting an innovation is positively related to its consistency with their value systems and procedures, which can reduce uncertainty towards the innovation (Su et al., 2017). Furthermore, there is empirical evidence suggesting that potential customers who perceive an innovation as being compatible with their existing values, past experiences and needs tend to form a positive attitude towards it. A study by Luna et al. (2017) validated the positive effect of customers’ perceived compatibility on their attitudes towards PMPS, while Liébana-Cabanillas et al. (2015) failed to validate this effect. Nevertheless, other researchers in the field of technology-based services’ adoption have concluded that customers form a positive attitude towards a service when it aligns with their values and past experiences (e.g. Taylor & Todd, 1995; Tan & Teo, 2000; Püschel et al., 2010; Del Bosque & Crespo, 2011; Lin, 2007; Amaro & Duarte, 2015). Based on the above, the following hypotheses are proposed:

H2a. Consumers’ perceived usefulness of PMPS directly and positively affects their attitudes towards them.

H2b. Consumers’ perceived ease of use of PMPS directly and positively affects their attitudes towards them.

H2c. Consumers’ perceived compatibility of PMPS directly and positively affects their attitudes towards them.

Concerning consumers’ normative beliefs, previous studies have considered both personal and non-personal factors as drivers of subjective norms (e.g. Taylor & Todd, 1995;

Bhattacharjee, 2000; Lin, 2007). This is based on the IDT (Rogers, 1995), which postulates that potential consumers of an innovation attribute credibility to personal and non-personal information from primary and secondary reference groups (Del Bosque & Crespo, 2011). Bhattacharjee (2000), Lin (2007) and Pedersen (2005) considered interpersonal and external influences as the defining components of subjective norms. Interpersonal influence reflects the influence of friends, colleagues and superiors through personal communication (e.g. word of mouth), while external influence includes mass media reports, leaders' suggestions and other information derived from non-personal sources (Lin, 2007). Thus, the following hypotheses are proposed:

H3a. Interpersonal influence concerning PMPS directly and positively affects consumers' subjective norms.

H3b. External influence concerning PMPS directly and positively affects consumers' subjective norms.

Perceived behavioural control includes two constructs referring to self-efficacy and facilitating conditions. Self-efficacy represents potential customers' perceptions of their capability to use a particular technology and facilitating conditions refers to the accessibility of the resources needed to perform particular behaviours (Taylor & Todd, 1995). Several studies have found that both variables, as defining components of perceived behavioural control, have highly significant effects on the acceptance of e/m-services (e.g. Tan & Teo, 2000; Bhattacharjee, 2000; Lin, 2007; Püschel et al., 2010; Del Bosque & Crespo, 2011). Thus, the following hypotheses are proposed:

H4a. Self-efficacy directly and positively affects perceived behavioural control.

H4b. Facilitating conditions directly and positively affect perceived behavioural control.

Extensions of the DTPB

The present study extends the DTPB in the field of PMPS using the theoretical frameworks of the TAM, IDT and perceived risk theory (Bauer, 1960) to develop an integrated model of customers' behaviours towards PMPS acceptance.

The first extension concerns the integration of the TAM and IDT frameworks with that of the DTPB. According to the TAM framework, the perceived usefulness of PMPS enhances the effect of perceived ease of use on attitude formation, thus suggesting a direct effect of perceived ease of use on perceived usefulness (Davis et al., 1989). Moreover, attitude partially mediates the relationship between perceived usefulness and behavioural intentions (Davis et al., 1989), suggesting a direct effect of perceived usefulness on behavioural intentions and highlighting the importance of PMPS' utilitarian benefits to potential customers. Numerous studies (Shaw, 2014; Dutot, 2015; Luna et al., 2017, 2019; Liébana-Cabanillas et al., 2017; Muñoz-Leiva et al., 2017; Ozturk, 2016) have empirically validated the positive effect of perceived ease of use on perceived usefulness; however, in the field of PMPS, there have been contradictory results regarding the effect of perceived usefulness on behavioural intentions when attitude mediates this relationship. Several studies fail to support the direct effect of perceived usefulness on behavioural intentions while providing strong empirical support for a full mediation effect of attitude between these two variables (e.g. Schierz et al., 2010; Muñoz-Leiva et al., 2017; Püschel et al., 2010; Luna et al., 2017). Conversely, other studies have provided empirical evidence suggesting a significant impact of perceived usefulness and attitude on behavioural intentions (e.g. Del Bosque & Crespo, 2011; Liébana-Cabanillas et al., 2017, 2018b; Luna et al., 2019; Liu et al., 2019). Prior studies in the field of PMPS in which the TAM2 was used to explain the PMPS adoption process validated the direct effect of perceived usefulness on behavioural intentions (e.g. Leong et al., 2013; Shaw, 2014; Shin & Lee, 2014; Tan et al., 2014; Dutot, 2015; Pham

& Ho, 2015; Ozturk, 2016; Ooi & Tan, 2016; Su et al., 2017; Zhao et al., 2019). Given the above, it is hypothesised that:

H5a. The perceived ease of use of PMPS directly and positively affects their perceived usefulness.

H5b. The perceived usefulness of PMPS directly and positively affects consumers' behavioural intentions.

Based on the IDT, it can be easier for individuals to assess the usefulness of an innovation if it is perceived as aligning with their existing needs and habits (Rogers, 1995). According to Liébana-Cabanillas et al. (2018a), consistency between potential customers' habits and values and PMPS enhances its perceived usefulness, while other technologies are rejected as they are perceived as more relevant to other types of lifestyle. Such studies have integrated perceived compatibility into the TAM and proposed its direct impact on both perceived usefulness and attitude (e.g. Schierz et al., 2010; Oliveira et al., 2016; Liébana-Cabanillas et al., 2018a). In line with these studies, the following hypothesis is proposed:

H6. The perceived compatibility of PMPS directly and positively affects its perceived usefulness.

The second extension of the DTPB refers to the role of environmental factors and exploits so-called internalisation mechanisms, suggesting the direct impact of subjective norms both on attitude and behavioural intentions (Venkatesh & Davis, 2000). Related empirical studies support the notion that potential adopters tend to form a positive attitude towards an m-service before they express intentions to use it (Kim et al., 2009) following a recommendation from a peer, industry expert or media report. Furthermore, the positive effect of subjective norms on attitude increases with m-services that are in the introduction or growth stage of their life cycle, during which the uncertainty level of potential customers is high. In the field of technology-based service adoption, previous research has shown that

consumers' subjective norms affect their attitude towards a specific behaviour (e.g. Pedersen, 2005; Kim et al., 2009; Schierz et al., 2010; Del Bosque & Crespo, 2011). More specifically, Pedersen (2005) validated the impact of subjective norms on perceived usefulness and suggested that users' beliefs about the usefulness of a new technology-based service are communicated through media and social networks and subsequently used by potential users of a service to help them form their expectations. Finally, Khalilzadeh et al. (2017) and Dutot (2015) found that as the number of PMPS users in society increases, the perceived usefulness of the service also increases. Hence, when the use of new technology is supported by the social context, the adoption decision process is positively affected. We thus hypothesise that:

H7. Consumers' subjective norms regarding the use of PMPS directly and positively affect their attitude.

H8a. Interpersonal influence regarding the use of PMPS directly and positively affects their perceived usefulness.

H8b. External influence regarding the use of PMPS directly and positively affects their perceived usefulness.

The final extension of the DTPB draws on perceived risk theory (Bauer, 1960), suggesting perceived risk as an additional salient dimension in determining customers' attitudes towards an innovation (Tan & Teo, 2000). The uncertainty regarding the consequences of a purchase decision can result in high levels of perceived risk. This is related to feelings of uncertainty or anxiety relating to the purchase and its possible negative outcomes (Featherman & Hajli, 2016). For technology-based services, perceived risk reflects customers' potential losses, rather than benefits, from using a service. Previous studies have suggested that when consumers evaluate a technology-based service, they form beliefs about the service's attributes and its potential use cases (e.g. Featherman & Hajli, 2016), which may include beliefs concerning poor performance and potential personal losses. These beliefs are

considered by consumers when assessing the risks of using a new technology-based service and ultimately affects their attitudes and behavioural intentions towards the service (Liébana-Cabanillas et al., 2018b). Using PMPS, as with other financial mobile services such as m-banking, is a potentially risky activity that may lead to negative consequences or unexpected losses (Yang et al., 2015). As customers tend to be risk-averse rather than utility optimisers when making risky decisions, perceived risk is considered a key determinant of potential PMPS adopters' behaviour (e.g. Tan et al., 2014; Slade et al., 2015a, 2015b; Ozturk, 2016; Yang et al., 2015; Pham & Ho, 2015; Lee et al., 2019; Zhao et al., 2019; Liu et al., 2019). Moreover, Al Kailani and Kumar (2011) found that the perceived risk associated with online purchasing is very high in highly risk-averse societies, which is expected to negatively affect PMPS adoption. Based on the above, the following hypotheses are proposed:

H9a. Consumers' perceived risk of using PMPS directly and negatively affects their attitude.

H9b. Consumers' perceived risk of using PMPS directly and negatively affects their behavioural intentions.

Based on the above research hypotheses, we aim to study the process of PMPS adoption through the model illustrated in the following figure.

--- Figure 1 about here---

Research Methodology

Data Collection

Data were collected using self-administered, structured questionnaires. Given the sampling frame unavailability and the limited research resources, convenience sampling was considered to be the appropriate method for data collection. A total of 1,020 questionnaires

were collected, of which 69 were excluded due to being incomplete, resulting in a sample of 951 responses. The complete demographic profile of respondents is listed in Table 2.

--- Table 2 about here ---

Measurement of Variables

Validated scale items from prior studies were used to secure the content validity of the measurement scales in our study. Regarding TAM and IDT, perceived usefulness was measured with four items adapted by Bhattacharjee (2001) and Schierz et al. (2010) for PMPS, perceived ease of use was tapped through four items proposed by Davis et al. (1989) and Schierz et al. (2010), perceived compatibility was scored through four items adopted by Tan and Teo (2000) and Schierz et al. (2010), and attitude and behavioural intentions were measured using the four-item scales proposed by Schierz et al. (2010). The five-item scale proposed by Schierz et al (2015) was used to measure perceived risk. The three-item scales proposed by Lin (2007) and Taylor and Todd (1995) were adopted to measure consumers' normative (i.e. subjective norms and their drivers – interpersonal and external influences) and behavioural control (i.e. perceived behavioural control and its determinants – facilitating conditions and self-efficacy) beliefs, respectively. The questionnaire also included a filter question to record awareness levels of NFC-PMPS. Following the procedure included in Luna et al. (2017), all individuals who advised that they were not aware of the service and did not understand how it worked were invited to view a video on YouTube explaining the features of NFC-PMPS.

All scale items were measured using a seven-point Likert scale from 1 'strongly disagree' to 7 'strongly agree'. A pilot study was conducted to check the reliability of all measurement scales. The results were satisfactory as all Cronbach's alpha values were above the recommended cut-off value of 0.70.

Analysis and Results

Existing research efforts largely use structural equation modelling (SEM) to examine the linear and compensatory relationships among the different variables of proposed models. Although PLS (and SEM) can be used to successfully test the statistical significance of linear relationships between variables (Hair et al., 2011), they are deemed less appropriate when the relationships are non-linear (Sharma et al., 2019; Kalinic et al., 2019). The linear modelling perspective assumes that weaknesses in one innovation adoption driver could be compensated by the improvement of another (Kalinic et al., 2019). However, recent studies on m-payment (and other technological services) adoption suggest that the investigation of the linear relationships between customers' willingness to adopt a technology-based service and their motivations is inadequate for understanding behaviour (Leong et al., 2018; Kalinic et al., 2019); instead, other methodologies may be more appropriate in assessing the non-linear and non-compensatory nature of these relationships (e.g. Chong, 2013; Liébana-Cabanillas et al., 2018a; Sharma et al., 2019; Kurtulmuşoğlu et al., 2019). To address this issue and in an attempt to model such complex non-linear relationships, researchers have tended to rely on artificial neural networks (ANN), which examine both linear and non-linear relationships between adoption drivers and customer behaviours. Although ANN score higher in predictive power and accuracy and outperform regression-based methodologies (such as linear regression or SEM), they cannot test causal relationships and as such are not suitable for hypothesis testing (Chan & Chong, 2012). To overcome this deficiency, we employed a hybrid approach (Chan & Chong, 2012; Leong et al., 2018; Sharma et al., 2019; Kalinic et al., 2019). First, partial least squares (PLS) methodology was used to assess the model validity (i.e. constructs' reliability and validity); then, both PLS and ANN were employed to verify the predictors of innovation adoption and rank their relative effect on the dependent variables.

Measurement Model Assessment

The construct reliability of the scales was measured using Cronbach's alpha and composite reliability. The Cronbach's alpha and composite reliability values (Table 3) ranged from .802 to .957 and .792 to .957, respectively, exceeding the standard value of 0.7, suggesting adequate construct reliability. Convergent validity was assessed by examining the size of factor loadings for each indicator and the average variance extracted (AVE). As shown in Table 3, all items loaded significantly on their respective latent variable and were above 0.7. Moreover, the AVE for each variable ranged from .623 to .886, well above the minimum required value of 0.5 (Hair et al., 2011). These results suggest that the variance explained by the construct is more than its error components, indicating convergent validity (Hair et al., 2011).

--- Table 3 about here ---

The discriminant validity of the constructs was assessed using the Heterotrait-Monotrait ratio (Henseler et al., 2015). Table 4 shows scores below the threshold of 0.85, thereby indicating acceptable discriminant validity.

--- Table 4 about here ---

Structural Model Results and Hypothesis Testing

The PLS method was used to confirm the hypothesised relationships in the proposed model and the significance of the paths included in the proposed model was tested using a bootstrap resampling procedure. In assessing the PLS model, the squared multiple correlations (R^2) for each endogenous latent variable were initially examined and the significance of the structural paths was evaluated. As shown in Figure 2, all path coefficients were found to be statistically significant at the 5% level.

--- Figure 2 about here ---

Concerning the TPB-related part of the model, the results allow for the verification of the positive effects of attitude ($\beta = .330$; $t = 9.025$), subjective norms ($\beta = .276$; $t = 8.833$) and perceived behavioural control ($\beta = .116$; $t = 4.034$) on behavioural intentions and the positive effects of subjective norms ($\beta = .230$; $t = 7.615$) on attitude. H1a, H1b, H1c and H7 are, therefore, supported. With regards to the influence of personal characteristics and PMPS' performance attributes on behavioural intentions to use the technology, the obtained empirical evidence supports the effects of perceived usefulness ($\beta = .122$; $t = 3.829$) and perceived risk ($\beta = -.161$; $t = -6.74$) on intention to use, confirming both H5b and H9b. Regarding customers' attitude formation towards PMPS, the results indicate that, among the technology's attributes, perceived usefulness ($\beta = .226$; $t = 5.416$) and perceived compatibility ($\beta = .205$; $t = 6.834$) play the most important role, followed by perceived ease of use ($\beta = .132$; $t = 4.041$) and perceived risk ($\beta = -.129$; $t = -4.919$). Hence, H2a, H2c, H2b and H9a are supported. Moreover, the results pertaining to the relationships among potential customers' beliefs regarding the technology's attributes and the social environment determinants support the positive influence of perceived compatibility ($\beta = .468$; $t = 13.596$), perceived ease of use ($\beta = .164$; $t = 3.920$), external influence ($\beta = .082$; $t = 2.896$) and interpersonal influence ($\beta = .078$; $t = 2.826$) on perceived usefulness, supporting H6, H5a, H8b and H8a. Regarding customers' beliefs regarding subjective norm formation, interpersonal influence ($\beta = .545$; $t = 30.264$) was found to be the most important determinant, followed by external influence ($\beta = .349$; $t = 17.064$); thus, both H3a and H3b are fully supported. Finally, potential customers' beliefs about their behavioural control over PMPS usage were found to be evenly affected by facilitating conditions ($\beta = .463$; $t = 13.549$) and self-efficacy ($\beta = .454$; $t = 12.392$), providing solid support for both H4b and H4a.

The proposed extended version of the DTPB, as indicated in Figure 2, demonstrates a high level of predictive power (R^2), as the model's constructs explain 40.5% of the variance

for perceived usefulness, 64.4% of the variance for perceived behavioural control, 59.1% of the variance for subjective norms, 55% of the variance for attitude and 60.5% of the variance for behavioural intentions.

ANN Analysis Results

Following Liébana-Cabanillas et al. (2018a), the multilayer perceptron (MLP) with the feedforward backpropagation training algorithm provided in SPSS 19.0 was used to rank the relative influence of the significant predictors obtained by PLS. The configuration of the ANN assumes that the number of predictor and dependent variables is equal to the number of neurons in the input and output layers of the ANN, respectively, and both are determined by the extended DTPB model's structure.

The research model depicted in Figure 1 was reconstructed into five ANN models, one for each of the five endogenous variables (Model A: SN, Model B: PBC, Model C: PU, Model D: ATT and Model E: BI), which are shown in Figure 3.

--- Figure 3 about here ---

Following similar studies in the context of technology acceptance, all of the models had one hidden layer with the number of neurons automatically provided by SPSS (Liébana-Cabanillas et al., 2018a). The sigmoid function was selected to activate the hidden and output layers (Liébana-Cabanillas et al., 2017; Ooi & Tan, 2016). All five models' inputs and outputs were also normalised to the range [0, 1] to ensure the increased effectiveness and performance of the model (Liébana-Cabanillas et al., 2018a). To avoid over-fitting, a 10-fold cross-validation procedure was performed, with 90% of the sample being used for the network's training and the remaining 10% for testing purposes (Liébana-Cabanillas et al., 2018a; Ooi & Tan, 2016). The adequacy of the sample size to run ANN was examined using Widrow's rule of thumb, as cited in Kalinic et al. (2019, p.147), 'the number of training examples should be approximately 10 times bigger than the number of weights in the

network'. Models D and E, which had the most input variables, consisted of five input, one output and three hidden neurons. They required 18 weights (5×3 for the input neurons, + 3 for biases) in the hidden layer and four weights (3 for the hidden neurons + 1 for bias) in the output layer. Our dataset ($856 = 951 \times 0.9$) was large enough to implement ANN as it was approximately four times bigger than the minimum cut-off value of 220 cases (22×10) that Widrow's rule of thumb anticipates as obtaining satisfactory results.

The root means square error (RMSE) values of the training and testing data sets for all five ANN models and ten neural network runs were computed to assess the predictive ability of the ANN (Liébana-Cabanillas et al., 2018a; Sharma et al., 2019), presented in Table 5. As all the RMSE mean values were small (between 0.076 and 0.112), it can be suggested that the ANN models accurately represent the relationships between the predictor and dependent variables (e.g. Liébana-Cabanillas et al., 2018a). To estimate the percentage of variance explained by each ANN model, the method proposed by Leong et al. (2018) was implemented, based on the formula $R^2 = RMSE/S^2$, where S^2 is the variance of each model output. The results, presented in Table 5, indicate a 93.2% variance for perceived behavioural control, 94.3% variance for subjective norms, 91.5% variance for perceived usefulness, 93.7% variance for attitude and 95.5% variance for behavioural intentions, as predicted by the relevant ANN input neurons. The predictive power superiority of the ANN (explaining more than 90% of the variability of the model's endogenous variables) suggests that this modelling perspective better addresses the complexities of the proposed model's variables and more adequately predicts potential PMPS consumers' behaviour.

--- Table 5 about here ---

The importance of each predictor was measured by how much the ANN predicted values changed for different predictor values (Chong, 2013). The relative importance values, calculated as the ratio of the absolute importance value divided by the largest importance

value, were used to express the result in percentages (Liébana-Cabanillas et al., 2018a). The absolute and relative importance results for all five ANN models are presented in Table 6.

--- Table 6 about here ---

Table 7 presents the similarities and differences between the PLS and ANN results, which can be explained by the non-linear and non-compensatory nature and the higher prediction power of the ANN models (Leong et al., 2013; Tan et al., 2014; Liébana-Cabanillas et al., 2018a). In Model A, the results are the same as those obtained with PLS, confirming that interpersonal influence has a stronger effect on subjective norms than external influence. The results of Model B indicate that the importance assigned to facilitating conditions and self-efficacy in determining perceived behavioural control is similar between the two approaches, confirming that facilitating conditions and self-efficacy play an equal role in perceived behavioural control formation. In Model C, the two methodologies produced similar results concerning the importance of the determinants of perceived usefulness. In both approaches, perceived compatibility had the most influence on the development of potential customers' beliefs regarding the usefulness of PMPS, followed by perceived ease of use and internal and external social factors.

--- Table 7 about here ---

The sensitivity analysis results of Models D and E contradict the PLS results. Specifically, in Model D, the order of importance obtained from the ANN suggests that the importance of perceived usefulness and subjective norms is greater than that of perceived compatibility, contrary to the findings obtained from the PLS. Additionally, for the two less important predictors of attitude, their ranking in the ANN sensitivity analysis indicated that, contrary to PLS analysis, the importance of perceived risk is greater than that of perceived ease of use in determining attitude. Finally, in Model E, the sensitivity analysis also

contradicts the PLS results, as the order of importance obtained from the ANN analysis suggests that the importance of subjective norms is greater than that of perceived ease of use in determining behavioural intentions, contrary to the findings obtained from the PLS.

Discussion and Conclusions

The purpose of this study was to investigate the factors affecting potential customers' behavioural intentions to use PMPS. An extended version of the DTPB was used as our theoretical framework. The theoretical contributions of the study are threefold. First, this is the first empirical study in the field of PMPS adoption to implement the DTPB extension, as previous comparative studies have shown the superiority of the DTPB over other theoretical innovation adoption frameworks. The proposed model integrates the TPB, TAM and IDT to describe the effects of the attitudinal, normative, control and uncertainty beliefs that potential customers hold regarding the use of this new technology-based service. The model exploits the strengths of all three theoretical acceptance models and also details the aforementioned consumers' beliefs to better understand the new technology adoption process (Del Bosque & Crespo, 2011). Second, this paper proposed a more detailed structure of the interrelationships among attitudinal and normative beliefs and their determinants to consider their direct and indirect effects on consumers' intentions to use PMPS. Third, this research employed an innovative approach integrating two different analytical techniques: a) correlation-based SEM analysis, which enabled the assessment of the linear relationships between the different constructs and b) ANN analysis, which allowed for consideration of the complexity and non-linearity of the relationships among the DTPB variables, to verify and/or improve the accuracy of the model in ranking each factor. Although this hybrid approach has been previously tested in the context of PMPS (Liébana-Cabanillas et al., 2018a; Sharma et al., 2019), no previous studies have used the DTPB as their theoretical research framework. The results of the two-step analysis confirmed many of the PLS findings but also suggested

different relative magnitudes for the effects of different factors influencing customers' attitudes and willingness to use PMPS. The findings of this research lead to several important implications for both researchers and practitioners.

Theoretical Implications

From a theoretical point of view, the PLS findings indicate that, per the studies of Liébana-Cabanillas et al. (2015, 2017), Luna et al. (2017, 2019) and Khalilzadeh et al. (2017), attitude and subjective norms, followed by perceived behavioural control, have the greatest impact on potential customers' willingness to use PMPS. The ANN sensitivity analysis, contrary to previous research, highlighted the role of subjective norms in determining potential consumers' intentions to adopt PMPS. Similar findings were reported in the meta-analysis by Liu et al. (2018), which also highlighted the greater importance of normative factors compared to attitudinal factors in predicting behavioural intentions to use PMPS. Moreover, Liébana-Cabanillas et al. (2018b) found that personal influence (integrating social norms and social image) is the main determinant of behavioural intentions, followed by attitude. Slade et al. (2015b) empirically validated the greater importance of social influence relative to other attitudinal constructs (i.e. expectations regarding effort and performance) in the context of remote PMPS. This result can be attributed to the fact that the high uncertainty associated with PMPS usage intentions, particularly in the early stages of the diffusion process, may lead potential customers to conduct a superficial rational technology-related evaluation of the service attributes and thus make a decision to adopt or reject the service based largely on existing customers' suggestions and mass media communications (Bhattacharjee, 2000; Filotto et al., 2020). However, given that attitude towards PMPS usage is a key determinant of behavioural intentions, it is expected that potential customers who favourably evaluate the anticipated outcome of PMPS usage are more likely to use them (Schierz et al., 2010; Del Bosque & Crespo, 2011; Tan et al., 2014; Luna et al., 2017, 2019).

Per previous studies in the field, the other two PMPS performance attributes concerning usefulness and riskiness were found to significantly affect consumers' intentions to use the service (e.g. Schierz et al., 2010; Slade et al., 2015a; Liébana-Cabanillas et al., 2017; Ozturk, 2016; Su et al., 2017; Zhao et al., 2019; Luna et al., 2019). These two utilitarian and rationally evaluated elements are significant in the adoption decision-making process (Del Bosque & Crespo, 2011); moreover, both PLS and ANN agree on the order of importance of these two factors. The results from both methodologies also suggest that the influence of perceived behavioural control on behavioural intentions, although significant, is smaller than that of attitude and subjective norms. This can be attributed to the high penetration of smartphones and their extensive use in various facets of everyday life which, in turn, enhances potential consumers' control over m-services usage, resulting in the higher levels of knowledge and resources that are essential to adopting the service (Bhattacharjee, 2000; Tan & Teo, 2000).

Furthermore, the DTPB framework identified four PMPS attributes (perceived usefulness, perceived ease of use, perceived compatibility and perceived risk) as significant determinants of attitude towards using the service. However, contrary to the results from PLS, perceived compatibility was ranked third in the ANN sensitivity analysis when relevant importance was assessed, while perceived usefulness was ranked first. The rankings of importance of the other three attitude determinants remained mostly unchanged. This suggests that when potential customers form their attitudes towards PMPS usage, they place greater value on the expected benefits of PMPS usage rather than on its perceived compatibility with their lifestyle. Similarly, when potential customers feel that PMPS is compatible with their needs, values and past experiences, or perceive it to be better, easier and safer to use compared to cash or credit cards, they are more inclined to use the service (e.g. Liébana-Cabanillas et al., 2015, 2017; Schierz et al., 2010; Amaro & Duarte, 2015).

Regarding the determination of normative and behavioural control beliefs, the results from both PLS and ANN agree that interpersonal influence is a more significant factor than external influence. Consumers' willingness to accept PMPS, as in other m-services contexts, is primarily influenced by the shared experiences of innovators and early adopters and then by non-personal sources (e.g. industry experts and mass media communications) (Lin, 2007; Del Bosque & Crespo, 2011). However, the latter could be interesting for managers seeking to enhance customers' awareness and trial rates in the early stages of a service's life cycle (Bhattacharjee, 2000; Lin, 2007). Facilitating conditions and self-efficacy were found to be equally important in shaping consumers' perceived behavioural control beliefs about PMPS use (Pedersen, 2005).

Finally, it is important to mention the central role of PMPS' usefulness regarding the other three technology-related attributes (i.e. perceived ease of use, perceived compatibility and perceived risk) and the determinants of social norms (Liébana-Cabanillas et al., 2017), where the outcomes of PLS remained unchanged after ANN implementation. Per Pedersen (2005) and Del Bosque and Crespo (2011), consumers' expectations of the utilitarian benefits (perceived usefulness) of PMPS are shaped by internal sources (the service's perceived compatibility, ease of use and level of risk) and external sources (information disseminated by their non-personal and interpersonal social contexts). These expectations then shape, to an extent, consumers intentions to use PMPS.

Practical Implications

From a practical perspective, understanding the importance of the different factors affecting consumers' willingness to use PMPS is useful to marketing managers who strive to increase service penetration. PMPS providers must consider consumers' dependency on their social context when forming their strategies and use the mass media to communicate positive testimonials of satisfied adopters to achieve multiple aims: educating potential consumers,

creating expectations of the PMPS' usefulness and increasing service awareness and trial rates. Furthermore, they must appropriately design and implement social media, phone and/or SMS campaigns with a focus on highlighting the key advantages of PMPS. Equally, it may be beneficial for businesses to incentivise existing users to share their positive experiences and thus contribute to new lead generation through positive word of mouth (Sharma et al., 2019). For this to be successful, managers must ensure that their potential consumers form a favourable attitude towards the service that can overcome any potential risks to using it. In light of the above results, attitude towards PMPS is influenced by certain utilitarian benefits provided by the service, namely, its usefulness, compatibility, and ease of use. Firms should, therefore, communicate the service's advantages in comparison to other payment options and deliver user-friendly interfaces to facilitate convenient service usage (Liébana-Cabanillas et al., 2017, 2018a). PMPS providers can benefit from the development of (social) media campaigns that include informational cues about the attributes of PMPS (Birch-Jensen et al., 2020). These cues may communicate convincing evidence about the usefulness of PMPS or highlight the benefits of having a more convenient, faster and safer online shopping experience (Sharma et al., 2019). However, promotions must emphasise the use of international standard security features to reduce potential consumers' perceived risk, which will eventually lead to increased scores in terms of attitude towards using PMPS and willingness to use PMPS (Ozturk, 2016; Sharma et al., 2019).

Limitations and Future Research

This study, despite the significance of its findings, has several limitations that narrow its scope. First, it followed a convenience sampling strategy that cannot ensure the full generalisability of the results. The proposed model can be used for further research using a random sampling approach, resulting in a more representative sample and the extraction of more trustworthy results. Second, and related, the fact that the study was conducted in Attica

may have affected the results and the generalisation of the results may not be widely accepted. Third, the findings and the implications of this research were obtained using a cross-sectional study. This reduces the ability of the study to reflect the temporal changes in the research constructs. A longitudinal study on the subject is necessary to clarify the effects of temporal changes. Furthermore, due to the globalisation of services, it is important to test the model across various countries with different cultures to identify differences or similarities.

Finally, although the extended DTPB provides a multitude of attitudinal, normative and control factors that affect PMPS adoption, additional factors should be considered to improve the model's predictability and applicability. For example, the effects of service providers' brand equity elements (e.g. brand image, brand associations and brand quality) on perceived risk and attitude development could be explored to understand the power of branding in PMPS diffusion (Chi, 2018). Moreover, the integration of individual characteristics (i.e. age, consumer innovativeness, mobility, prior experience, need for control and novelty-seeking) as moderators into the proposed model (Heidenreich & Handrich, 2015) would allow marketers to better understand the PMPS adoption decision process for different types of consumers and appropriately adjust their marketing mix.

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