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The Technology Acceptance Model (TAM) has received considerable research attention in the IS field over the past decade, placing an emphasis on the roles played by perceived ease-of-use and perceived usefulness in influencing technology adoption decisions. Meanwhile, alternative sets of antecedents to adoption have received less attention. In this paper, sets of antecedent constructs drawn from both TAM and the Perceived Characteristics of Innovating (PCI) inventory are tested and subsequently compared with one another. The comparison is done in the context of a large-scale market trial of a smart card-based electronic payment system being evaluated by a group of retailers and merchants. The PCI set of antecedents explains substantially more variance than does TAM, while also providing managers with more detailed information regarding the antecedents driving technology innovation adoption.
(*TAM*; *PCI*; *Adoption*; *Managers*; *Perceptions*; *Attitudes*; *Intentions*; *Field Study*; *High Technology*; *Smart Cards*)

Over the past decade, researchers within the information systems (IS) community have sought to conceptualize, empirically validate, and extend various models of individual-level information technology adoption and usage. These models have generally attempted to use key antecedent attitudinal constructs drawn from established psychological theories to predict new IS technology adoption. For example, the Technology Acceptance Model (TAM) proposed by Davis et al. (1989) to explain IS adoption in a variety of contexts incorporates Fishbein and Ajzen's Theory of Reasoned Action (1975) as its theoretical foundation.

TAM has become one of the most widely applied individual-level technology adoption models in the IS

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literature. Several alternative models of technology adoption have been proposed in an attempt to overcome the limitations of TAM by incorporating additional constructs suggested by theories other than the Theory of Reasoned Action (TRA). For example, Mathieson (1991) proposed a model of technology adoption premised on Ajzen's (1991) Theory of Planned Behavior that expands TAM to include two additional constructs. Other efforts have sought to develop measures of actual system acceptance as opposed to intended usage (Szajna 1996), and to identify important additional antecedent constructs that also underlie the technology adoption decision, such as computer self-efficacy (Compeau and Higgins 1995) and the role of prior experience (Taylor and Todd 1995a).

Although these conceptual and empirical advances have helped IS researchers to better understand the antecedents to technology adoption, at least two broad concerns remain. First, TAM is often employed because of its parsimony and robustness, allowing the user to explain considerable variance while using only two antecedents (perceived usefulness and perceived ease-of-use). However, although parsimony is an important consideration, individual responses to new technologies are likely to differ depending on the context within which they are encountered. Complete understanding of adoption behavior requires a model that captures the richness of the adoption process across many different contexts.

Second, much of the existing IS adoption literature has focused on the adoption of new behaviors, such as the usage of a personal computer or a particular software package. In these studies, subjects are typically asked to assess innovations that are described across a limited range of possible benefits, and to make adoption decisions that involve minimal acquisition costs. Fewer field-based tests of technology adoption models have been undertaken, although their number is growing (for one exception in a marketing context, see Taylor and Todd 1995b). This latter stream of research is important because individuals and firms making decisions in the field must augment their concerns about price/performance issues with more qualitative assessments of image and visibility. Furthermore, the costs of adoption are typically quite large in these settings. Thus, to assess the generalizability of the proposed technology adoption models, it is important to study their application across both experimental and field-based settings.

In this paper, we assess the value of including a wider variety of adoption antecedents to predict technology adoption. In a head-to-head study, we compare TAM's antecedents to the Perceived Characteristics of Innovating (PCI) antecedents developed by Moore and Benbasat (1991). Using Rogers' Diffusion of Innovations theory (1995), Moore and Benbasat developed a robust, reliable, and valid set of 8 constructs that are key antecedents to technology adoption decisions. Despite their attractive conceptual and measurement properties, however, relatively little empirical use has been made of the PCI constructs (for notable exceptions, see Agarwal and Prasad 1997, 1998; Chin and Gopal 1995, Gagliardi and Compeau 1995, Moore and Benbasat 1994). No previous study has directly compared the performance of these two models.

The TAM and PCI antecedents are examined in the context of an ongoing market trial of a smart card payment system—a point-of-purchase technology that electronically conducts and manages purchase transactions. Specifically, we examine retailer and merchant interest in adopting this new technology for use in their own businesses. Our primary purpose in conducting this study is to determine which model provides a more complete explanation of variance in the context of a real-world adoption decision. We find that when used as antecedents to adoption intention, the PCI belief constructs explain a higher proportion of the variance than TAM. Thus, our results suggest that there is value in sacrificing parsimony to include a richer set of antecedents to predict adoption.

The remainder of the paper is organized as follows. First, TAM and the PCI belief constructs are briefly reviewed. Next, the empirical setting in which these models are tested is described, along with a discussion of the sample, research method employed, and results. This is followed by a discussion of the study's key findings, along with its broader implications for IS technology adoption research. Finally, the paper concludes by acknowledging the key limitations of the study, as well as offering suggestions for additional research.

Literature Review

The Technology Acceptance Model (TAM)

TAM builds primarily from the theory of reasoned action (Fishbein and Ajzen 1975) but also draws from expectancy theory (Robey 1979, Vroom 1964) and self-efficacy theory (Bandura 1977, 1982). TAM proposes that two specific belief constructs—perceived usefulness (the extent to which a technological innovation is expected to improve the potential adopter's performance) and perceived ease-of-use (the degree to which the potential adopter expects a technological innovation to be free of effort in use)—are the critical antecedents to an individual's technology adoption decision (Davis 1989).

TAM has seen many applications and extensions in the IS field since its development. Some applications have tested the correlation between innovation usage as predicted by TAM and actual usage behavior (e.g., Szajna 1996), or between self-reports of intended IS usage to actual usage (Straub et al. 1995). TAM has been used to assess the IS adoption characteristics of small firms (Igbaria et al. 1997), to examine adoption differences between genders (Gefen and Straub 1997), and across diverse cultures (Phillips et al. 1994, Straub et al. 1997). Other work has sought to either extend TAM by adding additional constructs to the core model (e.g., Jackson et al. 1997, Taylor and Todd 1995a) or by pursuing a deeper understanding of the two antecedent constructs that predict behavioral intent (e.g., Venkatesh and Davis 1996).

The Perceived Characteristics of Innovating (PCI) Belief Constructs

The PCI belief constructs proposed by Moore and Benbasat (1991) draw on earlier conceptual work by Rogers (1995). Rogers' diffusion of innovations perspective incorporates five innovation characteristics as antecedents to any adoption decision: relative advantage, compatibility, complexity, trialability, and observability (Rogers 1995). PCI incorporates three of these constructs—relative advantage, compatibility, and trialability—as originally proposed. Relative advantage represents the degree to which an innovation is perceived to be superior to current offerings. Compatibility is the degree to which an innovation meshes with the adopter's current habits and practices. Trialability represents the extent to which a potential adopter believes that the innovation can be adequately tried prior to the adoption decision. Moore and Benbasat (1991) renamed a fourth construct in Rogers' model—complexity—as ease-of-use to be consistent with other emerging models of adoption in the IS literature (e.g., Davis 1989). Ease-of-use represents the degree to which an innovation is perceived to be easy to use.

Four additional constructs are included in the PCI set: visibility, image, result demonstrability, and voluntariness. Arguing that Rogers' observability construct was not specific enough for usage in IS contexts, Moore and Benbasat (1991) proposed two more distinct constructs in its place: visibility (the degree to which an innovation is visible during its diffusion through a user community) and result demonstrability (the degree to which the benefits and utility of an innovation are readily apparent to the potential adopter). Image—which Rogers originally included as part of the relative advantage construct—represents the degree to which an individual believes that the adoption of an innovation will bestow them with added prestige in their relevant community. Finally, voluntariness reflects the extent to which innovation adoption is perceived to be under the potential adopter's volitional control.

Despite its theoretically rich development and fairly rigorous initial testing, the full set of PCI belief constructs has received relatively little empirical attention (exceptions are Agarwal and Prasad 1997, Gagliardi and Compeau 1995, Moore and Benbasat 1994). IS researchers often cite or discuss Moore and Benbasat's PCI constructs as valid and reliable candidates for modeling various technology adoption decisions or empirical settings only to subsequently dismiss them or reduce the number of belief constructs employed.[1]

[1]For example, Chin and Gopal (1995) restricted their usage to relative advantage, ease-of-use, and compatibility in their examination of a GSS adoption decision, arguing that the other dimensions were not relevant in their study context. Similarly, Agarwal and Prasad (1998) included only relative advantage, ease-of-use, and compatibility in a study of WWW usage intentions. In fact, a meta-analysis of previous work on innovation characteristics by Tornatzky and Klein (1982) found that only relative advantage, ease-of-use, and compat-

This is unfortunate because Moore and Benbasat developed the PCI constructs with the intention that they would "... be generally applicable to a wide variety of innovations... The resulting instrument is ... general enough to be used, with slight modifications, in most diffusion studies" (Moore and Benbasat 1991, p. 194).

TAM Versus PCI

Our primary concern here is on a comparison of the prediction performance of the belief constructs used in TAM with the PCI belief constructs. TAM is used as the comparison model both because it has been the most widely studied model in previous research and because it is prized for its parsimony. Furthermore, the set of constructs used in TAM is essentially a subset of those proposed by PCI. Thus, any difference in predictive ability between the two models can be attributed primarily to differences in the sets of innovation characteristics they use.

Many existing comparative studies have employed student subjects faced with hypothetical adoption decisions for relatively simple and familiar IS innovations such as a new word-processing package (Davis et al. 1989), a new spreadsheet package (Mathieson 1991), or a shared computing facility (Taylor and Todd 1995c). The current study adds to this literature base by conducting a comparative assessment of TAM versus PCI using data collected via a survey done in a naturally occurring, real-time, field-based adoption setting.

Method

Empirical Setting

A technology with significant managerial implications (e.g., Bowers and Singer 1996, Crane and Bodie 1996, Humphrey 1996) and many implementation-based challenges (for example, Komenar 1997)—the smart card—was selected to comparatively test the various sets of adoption antecedents. A smart card is a small, credit card-like instrument that can be used for many purposes. Smart cards differ from conventional plastic credit cards in that they contain a tiny embedded microprocessor. This allows the smart card to store significant amounts of electronic information (both logic and data), thereby permitting the execution of more sophisticated transactions.

For example, once merchants have adopted the point-of-purchase equipment needed for this new technology, consumers can use a smart card as a substitute for cash in everyday retail consumption situations (Blackwell 1997, Souccar 1998). Operationally, an individual first purchases a card from her/his financial institution with a prespecified amount of money loaded into its memory. These funds can then be applied to the purchase of goods or services from merchants, just as normally would occur with cash, checks, or credit and debit cards. When the smart card's balance approaches zero, it can be credited with new funds through a bank machine, pay phone, or remote PC (Komenar 1997).

A smart card system known as "Exact" was test-marketed by three large Canadian banks in one mid-sized city for a full calendar year in 1997, with a national roll-out and full market deployment planned thereafter. At the height of the trial, over 400 businesses had equipped their retail establishments and services with the Exact system's point-of-sale equipment, and more than 5,000 consumers possessed an Exact card (Blackwell 1997).

The Exact card trial represented an excellent, field-based empirical domain in which to test the alternative antecedent structures. Past research has demonstrated that many small business owners (such as merchants and retailers) are resistant to new ways of conducting transactions, particularly when such innovations involve real or perceived increases in task or operational complexity (e.g., Frambach et al. 1998, Igbaria et al. 1997). At the same time, merchant acceptance of the new technology is critical to its overall market success. Thus, an examination of merchants' intentions to adopt the Exact card technology and the antecedents to these intentions represents a realistic context within which to conduct our comparative analysis.

Modeling Approach

Our primary objective is to compare the performance of the antecedents of TAM to the PCI set of antecedents

ibility have been found to be consistently related to adoption. However, the point remains that other innovation characteristics can be important in specific adoption contexts.

in predicting adoption intention. To focus on the comparison between these sets of antecedents, we construct several different models that relate these antecedents directly to intention to adopt. We model TAM as specified by Davis (1989). For the PCI constructs, we develop a model that directly relates each of the eight adoption antecedents to intention to adopt. We refer to this as the full PCI model.[2]

Measures

The measures for TAM were operationalized as closely as possible to the original items proposed by Davis (1989). For the PCI belief constructs, we utilized the short-form scale subset of 25 measurement items recommended by Moore and Benbasat (1991).[3] For both models, the measures had to be modified somewhat to fit both the merchant and Exact card contexts (see the Appendix for precise item wordings). Items were operationalized to assess the merchant owner's perception of the payment system and its possible role as a point-of-sale technology. All items were measured by 7-point Likert scales anchored by "strongly disagree" and "strongly agree."

Four items were used to determine the degree to which merchants planned to adopt the Exact card technology following the market trial (intention to adopt). These items were adapted from existing IS behavioral intent measures that are task-focused and are designed to capture a respondent's sense of urgency for formally adopting an innovation after it becomes broadly available (Mathieson 1991, Taylor and Todd 1995c, Venkatesh and Davis 1996). As noted by Davis et al. (1989, p. 991), TAM is "used to explain a specific behavior (usage) toward a specific target . . . with a specific context." Thus, existing measures of intention had to be modified to reflect both the current target (the Exact card technology) and context (all participating merchants were already using the system). In this case, a stated intention to adopt the technology in the future (following the trial period) is equivalent to a decision to continue its use. Thus, three of the four intention measures used here refer to "continued use" or "permanent adoption." They are quite similar in form to the items used by Agarwal and Prasad (1998, 1999) to measure future usage intentions. The fourth item—"I will recommend that my fellow merchants get a smart card payment system"—represents a different behavioral intention following adoption. We recognize that this item is not entirely consistent with measures used in previous studies. However, we believe that its inclusion can potentially enhance the content validity of the intention construct in the current study context. Whether or not it deserves to be included with the other measures is ultimately an empirical issue.

Data Collection Procedure

Our measures were initially tested in a small-scale pilot study. Results from the pilot study led to several changes in item wordings and a few minor changes in item ordering in the final version of the questionnaire. The full survey was administered at the 10-month point of the year-long Exact card system market trial. This ensured that the merchants involved in the trial had had a reasonable amount of time to use and consider the innovation, while also allowing us time to finish the survey's administration and follow-up procedures before the market trial had officially concluded. The cover letters, survey design, timing, and follow-up procedures outlined by Dillman (1979) were closely adhered to in the execution of this research.

The sampling frame for this study consisted of merchant and retailer institutional clients of the three banks conducting the Exact card trial. We obtained lists of participating merchants from all three banks. These lists proved to be highly accurate, up-to-date, and generally reliable. However, to ensure surveys and cover letters were addressed to the correct person in each business, all merchants were first contacted by telephone to ensure that the individual who made the decision to participate in the Exact trial and who would ultimately decide whether or not to adopt the payment system had been correctly identified by the bank. When discrepancies occurred, the contact information was corrected.

[2]We refer to the models that we form using the PCI antecedents as PCI models even though PCI was developed as a measurement instrument and not a technology adoption model per se.

[3]For three constructs—voluntariness, visibility, and trialability—the Moore and Benbasat short-form scale included only two items. For these constructs, the survey was expanded to include additional measures drawn from the full set of items reported in Moore and Benbasat (1991). The Appendix reports only those items retained in our final PCI model.

Sample

Questionnaires were sent to all of the merchants involved in the Exact payment system trial with whom contact could be established (379). A total of 176 completed questionnaires were returned, representing a response rate of 46.4%. To determine whether nonresponse bias was an issue, we used the procedure outlined by Armstrong and Overton (1977) to compare early with late responders. No significant differences in any of our measures were noted.

The representativeness of the achieved sample appears to be good. Participating merchants ranged in size from large chain retailers to small sole proprietorships; from multinational fast-food outlets to fine dining establishments. Other types of businesses represented in the sample include dry cleaners, pharmacies, gas stations, bookstores, CD shops, second-hand clothing stores, and various government-run agencies (e.g., licensing bureaus, post offices, liquor and beer stores). One-third of the merchants reported annual revenues of less than $250,000, while nearly 30% claimed revenues in excess of $1 million per year. The number of front-line employees who regularly used the Exact system during the trial ranged from a few employees for some merchants to more than 200 for others. Finally, responding merchants also accepted most conventional forms of retail payment, including cash, checks, and credit and debit cards.[4]

[4]One reviewer raised the very legitimate concern that because many larger organizations appear to be included in our sample we are really studying organizational rather than individual adoption decisions. Although it is not possible to completely address this issue, we believe that it is not a major concern for the following reasons. First, the contact names provided by the banks identified those individuals responsible for making the original decision to participate in the trial. Presumably, these same individuals are also likely to make any subsequent adoption decisions. Second, as part of the survey, responses to questions about number of employees, retail square footage, and annual revenues were collected for each participating organization. A preliminary factor analysis of these items lead to a single-factor solution (eigenvalue = 2.06; variance explained = 68.7%; loadings = 0.90, 0.80, and 0.78, respectively). Using the resulting factors scores, we median split the sample into two groups: small and larger firms. We then conducted a MANOVA using this size factor as the independent variable and the individual measurement items as the dependent variables. The resulting F-value was not significant ($F(40, 131) = 0.75$), and none of the univariate tests were significant either. Thus, there do not appear to be any systematic differences in the responses provided by small versus larger organizations.

Missing Data

Although most responding merchants provided full information for the constructs and measures of interest, four merchant questionnaires had to be discarded due to an unacceptably large number of missing responses (i.e., they were case-wise deleted). This left 172 completed questionnaires. In eight of these cases, merchants answered most—but not all—of the items pertaining to the constructs of interest. To retain these cases for further analysis, we followed the data imputation procedures recommended by Hair et al. (1995) and Roth et al. (1999). Specifically, we used the mean-person imputation approach to take advantage of responses to some (but not all) of the items relating to a particular construct. Using simulations, Roth et al. (1999) demonstrated that this method of data imputation does not substantially bias subsequent data analyses. Thus, our final sample size is 172.

Analysis and Results

Partial Least Squares (PLS) Modeling

As discussed by Rogers (1995) and others, it is reasonable to expect that the nature and importance of the antecedents to adoption will vary across adoption settings. As such, a key objective in technology adoption modeling should be to maximize the variance explained in the dependent construct, intention to adopt, putting an emphasis on the goal of prediction. Furthermore, our achieved sample size is smaller than the minimum recommended for covariance-based modeling approaches such as LISREL and AMOS (Chin and Newsted 1998). For both of these reasons, our models were estimated using Partial Least Squares (Barclay et al. 1995, Wold 1982). The main purpose of PLS is to maximize the variance explained for the endogenous constructs in a model.[5]

[5]More correctly, a PLS model that uses reflective indicators (as is the case here) will attempt to maximize the explained variance in the items associated with the endogenous construct(s). However, in doing so it will also maximize the variance explained in the endogenous construct(s) themselves.

Measurement Model Results

PLS Graph (version 2.91.03.04) was used to estimate both TAM and the full PCI model. The adequacy of a measurement model can be determined by looking at: (1) individual item reliabilities, (2) the convergent validities of measures associated with individual constructs, and (3) discriminant validity between constructs (Hulland 1999). For TAM, the loadings were all greater than 0.7. For the PCI model, several items did not load well on their underlying constructs. To alleviate this problem, one item each was dropped from the result demonstrability, visibility, and trialability constructs, leaving three, two, and two measurement items, respectively. All retained items had loadings of at least 0.65.

Table 1 reports the numbers of items, means, and standard deviations for each of the constructs studied. An assessment of convergent validity (internal consistency) is also included, by construct (Fornell and Larcker 1981). In general, researchers look for values on this latter measure to exceed 0.70 (Nunnally 1978). As Table 1 shows, all of the constructs have internal consistency values that exceed this recommended threshold.[6]

Table 1 Construct Means, Standard Deviations, and Internal Consistencies

Construct	Number of Items	Mean	Standard Deviation	Internal Consistency
TAM				
Perceived Ease-of-Use	6	5.40	1.37	0.94
Perceived Usefulness	6	3.52	1.74	0.98
PCI				
Relative Advantage	5	3.57	1.60	0.94
Ease-of-Use	4	5.56	1.41	0.93
Compatibility	3	4.06	1.85	0.94
Image	3	2.78	1.71	0.97
Result Demonstrability	3	3.76	1.04	0.87
Visibility	2	2.72	1.05	0.84
Trialability	2	3.96	1.69	0.76
Voluntariness	2	6.32	1.24	0.91
Intention to Adopt	4	3.78	1.88	0.94

To assess discriminant validity among the constructs, Fornell and Larcker (1981) suggest the use of average variance extracted (AVE), the average variance shared between a construct and its measures. As Table 2 shows, the AVE values are consistently greater than the off-diagonal correlations, suggesting at least moderate discriminant validity at the construct level.[7] However, it is possible (particularly given the relatively high between-construct correlations in Table 2) that individual measurement items may not exhibit adequate discriminant validity. To check this, a matrix of loadings and cross-loadings was constructed for the PCI model (see Table 3).[8] As this table shows, although some of the cross-loadings are quite high, in all cases the items load more highly on their intended constructs than on other constructs. Thus, discriminant validity can be considered adequate for this model.

Structural Model Results

Table 4 summarizes the structural model results for both TAM and the PCI model. For TAM, all three paths are significant. The model does a good job of explaining variance in both perceived usefulness ($R^2 = 28.2\%$) and intention to adopt ($R^2 = 32.7\%$). This explanatory power is based more on the effect of perceived usefulness (as demonstrated by the values in the final column of Table 4) than on perceived ease-of-use, a result that is consistent with earlier work.

The PCI model explains 45.0% of the variance in intention to adopt, a value that is noticeably higher than

[6]As noted earlier, there was some concern as to whether or not the four intention measures would all load on the same construct. The results from PLS reported here suggest that this was the case. To further examine this issue, we conducted a confirmatory factor analysis for TAM using AMOS to assess whether a two-item or four-item set of intention measures provided better overall model fit. The chi-squares for the four intention item model (242.10, df = 101) and the two-item model (208.17, df = 74) did not differ significantly from one another. Thus, we elected to retain all four items in our PLS models.

[7]Table 2 includes correlations between the TAM and PCI constructs for the sake of completeness. Not surprisingly, TAM's perceived ease-of-use and PCI's ease-of-use constructs are highly correlated. Similarly, perceived usefulness (TAM) and relative advantage (PCI) are also highly correlated. The estimated models use only one of the two constructs from each of these sets.

[8]Discriminant validity between the measures used in TAM was not a problem.

Table 2 Correlations Among Constructs & Average Variance Extracted

Construct	1	2	3	4	5	6	7	8	9	10	11
1. TAM—Perceived Ease-of-use	**0.85**										
2. TAM—Perceived Usefulness	0.53	**0.94**									
3. PCI—Relative Advantage	0.52	0.96	**0.88**								
4. PCI—Ease-of-Use	0.97	0.47	0.48	**0.88**							
5. PCI—Compatibiity	0.52	0.72	0.77	0.49	**0.92**						
6. PCI—Image	0.26	0.56	0.60	0.24	0.59	**0.96**					
7. PCI—Result Demonstrability	0.30	0.26	0.31	0.28	0.33	0.23	**0.83**				
8. PCI—Visibility	0.18	0.13	0.16	0.19	0.19	0.19	0.13	**0.85**			
9. PCI—Trialability	0.34	0.26	0.33	0.30	0.34	0.24	0.36	0.14	**0.78**		
10. PCI—Voluntariness	0.29	0.17	0.15	0.28	0.19	0.05	0.20	0.05	0.02	**0.91**	
11. Intention to Adopt	0.38	0.56	0.60	0.34	0.58	0.50	0.30	0.26	0.36	0.14	**0.89**

Notes

1. Diagonal **bolded** values are the square root of the variance shared between each respective construct and its measures. Off-diagonal values are the correlations among constructs. To demonstrate discriminant validity, a diagonal value should exceed all of the off-diagonal values in the same row and column (Hulland 1999).
2. The interconstruct correlations were calculated using factor scores based on the PLS model results.

that obtained using TAM ($\Delta R^2 = 12.3\%$). Six of the PCI model's antecedent constructs have a significant effect on intention to adopt: relative advantage, compatibility, image, visibility, trialability, and voluntariness.

TAM Versus PCI

Although TAM is theoretically nested within the PCI model, this is not true empirically.[9] Thus, we could not assess directly whether the full PCI model explained significantly more variance in intention to adopt than TAM using the results already presented. Instead, we estimated a reduced PCI model (using the PCI measures) that only included the relative advantage and ease-of-use constructs. This model is very similar to that estimated for TAM, but uses slightly different items to measure the antecedent constructs. This reduced model explained 36.2% of the variance in intention to adopt, a value significantly lower than that found for the full PCI model that includes all eight antecedents ($F_{6,\,163} = 4.35$, $p < 0.001$). Thus, using the full set of PCI innovation characteristics adds significantly to the prediction of adoption intent.[10]

Discussion

A fair comparison of competing theories or models requires careful empirical design, operationalization, and measurement (Cooper and Richardson 1986). We believe that such a comparison has been made here between belief constructs used in technology adoption models. A key aspect of our research design is that all tests were conducted in the same empirical context using the same set of respondents. Furthermore, the merchants surveyed in our study were actively considering adoption of the Exact technology, resulting in high

[9]As Table 2 shows, while the TAM and PCI ease-of-use and usefulness/relative advantage measures are closely related, they are not identical due to the use of slightly different sets of measurement items.

[10]Previous adoption studies have tended to find that only relative advantage, ease-of-use, and compatibility consistently achieve significance (Rogers 1995, Taylor and Todd 1995b). We estimated a third PCI-based model that used only these three exogenous constructs to predict intention to adopt. This reduced, three-antecedent model explained 39.0% of the variance. Although this model explains significantly more variance than the model that includes only relative advantage and ease-of-use ($F_{1,\,168} = 7.53$, $p < 0.01$), it still explains significantly less variance than the full PCI model ($F_{5,\,164} = 5.37$, $p < 0.001$). Thus, the current results argue strongly for use of the full set of eight PCI innovation characteristics in technology adoption studies.

Table 3 Loadings and Cross-Loadings, PCI Model, by Construct

ITEMS	RA	EOU	COMPAT	IMAGE	RESDEM	VISIB	TRIAL	VOLUN	INTENT
Relative Advantage									
Item 1	.875	.385	.704	.592	.364	.129	.350	.057	.544
Item 2	.811	.359	.673	.548	.264	.180	.307	.053	.524
Item 3	.857	.451	.654	.395	.240	.127	.216	.199	.523
Item 4	.930	.439	.663	.557	.228	.124	.272	.159	.524
Item 5	.926	.489	.708	.541	.270	.153	.298	.208	.521
Ease-of-Use									
Item 1	.232	.807	.297	.089	.178	.019	.232	.243	.195
Item 2	.508	.863	.492	.271	.231	.253	.295	.213	.374
Item 3	.391	.913	.394	.178	.268	.162	.266	.268	.260
Item 4	.469	.913	.479	.235	.291	.162	.260	.264	.320
Compatibility									
Item 1	.633	.428	.857	.467	.252	.133	.281	.183	.446
Item 2	.755	.482	.949	.558	.310	.156	.317	.189	.559
Item 3	.734	.447	.946	.581	.330	.230	.336	.155	.570
Image									
Item 1	.572	.197	.559	.964	.225	.136	.222	.035	.480
Item 2	.587	.229	.588	.962	.236	.195	.254	.048	.497
Item 3	.558	.257	.533	.941	.210	.219	.222	.044	.461
Result Demonstrability									
Item 1	.264	.297	.315	.159	.858	.070	.284	.249	.247
Item 2	.237	.232	.257	.148	.819	.082	.325	.154	.226
Item 3	.268	.176	.240	.263	.806	.152	.291	.105	.277
Visibility									
Item 1	.177	.199	.203	.215	.122	.952	.165	.098	.277
Item 2	.068	.100	.093	.064	.087	.731	.039	−.081	.125
Trialability									
Item 1	.314	.179	.296	.156	.283	.100	.881	−.091	.332
Item 2	.184	.345	.236	.256	.299	.135	.677	.171	.214
Voluntariness									
Item 1	.154	.265	.200	.038	.169	.056	.002	.914	.127
Item 2	.126	.243	.146	.043	.199	.032	.025	.913	.126
Intention to Adopt									
Item 1	.551	.348	.567	.441	.307	.221	.301	.128	.930
Item 2	.525	.340	.529	.445	.307	.251	.343	.143	.946
Item 3	.463	.237	.453	.360	.164	.118	.261	.032	.830
Item 4	.576	.288	.492	.518	.284	.307	.353	.167	.843

decision involvement (Feldman and Lynch 1988). Thus, we believe that the differences observed in our results can be attributed primarily to specific differences in the characteristics of the models and belief constructs themselves, as opposed to the empirical setting in which they were applied.

Summary and Implications

Our results show that when modeled as adoption antecedents, the PCI belief constructs explain substantially more variance in adoption intent than the TAM antecedents (an improvement of roughly 12%). In terms of which model is best for broad usage within IS, both the TAM and PCI belief constructs are highly intuitive, reliable, and have considerable explanatory power in terms of assessing a potential adopter's intention to adopt a new technology. Given this, one could defensibly use either set. However, while TAM presents a more parsimonious set of belief constructs than PCI and, as such, places fewer strains on both respondents and researchers, the difference in information requirements for the two models is relatively small. Specifically, TAM requires responses to twelve measurement items, whereas the short-form PCI instrument requires twenty-five responses. Furthermore, the eight antecedent constructs included in the PCI set provide IS researchers with a descriptive richness that is largely missing from TAM.

More importantly, our results suggest that reliance on TAM can at times be misleading. For example, a merchant looking at the TAM results reported in Table 4 would conclude that the usefulness construct plays a key role in explaining intention, while ease-of-use is also quite important. In contrast, the PCI results suggest that while relative advantage (which is extremely similar to usefulness) plays a significant role in affecting adoption intention, many of the other characteristics are also important. Furthermore, ease-of-use is no longer a significant predictor of intention. Thus, a manager relying on the TAM results could potentially use wrong approaches in trying to increase merchant adoption of the new technology.

Our results are not unique in this regard. Other studies that have employed either the full or a reduced set of the PCI characteristics have generally found that constructs other than relative advantage and ease-of-use are significantly linked to adoption intentions, although the specific set of significant predictors varies by study. For example, Agarwal and Prasad (1997) found that compatibility, visibility, trialability, and voluntariness all had a direct and significant effect on Internet usage, whereas the effects of relative advantage and ease-of-use were not significant. They also found that for intention, only relative advantage and demonstrability were significant predictors. Similarly, in a study of Canadian government employees' reactions to the potential adoption of smart card technology, Gagliardi and Compeau (1995) noted that while relative advantage and ease-of-use were both significant predictors of adoption intent, image, demonstrability, visibility, trialability, and voluntariness were also all significant predictors. Finally, Chin and Gopal (1995) studied MBA students' intentions to adopt a GSS using a reduced set of PCI characteristics, and found that compatibility was a more important predictor than either usefulness (they used the TAM measures) or ease-of-use. They also found a significant direct effect between enjoyment (not part of PCI) and intention that was stronger than the effects of either usefulness or ease-of-use. The results of these studies,

Table 4 PLS Structural Model Results, Path Significance Levels, and Percentage of Explained Variance on "Intention to Adopt"

Construct	Path Coefficient (ß)	% of Total Explained Variance in "Intention to Adopt" Accounted for by Each Antecedent Construct
TAM		
Path from Ease-of-Use to Usefulness	.531***	—
R^2—Usefulness	28.2%	—
Perceived Ease-of-Use	.108*	42.6%
Perceived Usefulness	.507***	57.4%
R^2—Intention to Adopt	32.7%	100%
PCI MODEL		
Relative Advantage	.291**	30.0%
Ease-of-Use	.005	0.5%
Compatibility	.167*	17.2%
Image	.162**	16.7%
Result Demonstrability	.053	5.5%
Visibility	.124*	12.8%
Trialability	.130*	13.4%
Voluntariness	.038*	3.9%
R^2—Intention to Adopt	45.0%	100%

Path Significance Levels:
***$p < 0.001$ **$p < 0.01$ *$p < 0.05$

Note. These significance levels are determined via jackknifing analysis (Fornell and Barclay 1983, Wildt et al. 1982).

taken together with the current findings, suggest the following two generalizations: (1) The PCI characteristics can have a direct impact on intentions even after controlling for the effects of usefulness (or relative advantage) and ease-of-use; and (2) The relative impacts of the individual PCI constructs (and, by extension, those in TAM) vary considerably across adoption contexts and dependent construct choices.

Limitations and Directions for Future Research

The current research has several limitations. First, the models tested here have been empirically assessed in only one adoption context. Because of this, the generalizability of the results reported here is not known beyond the current sample and smart card technology adoption context. Given the higher explanatory power demonstrated by the full PCI model (versus TAM) in this study, further examination of the PCI belief constructs' merits in other technology adoption contexts should be a high priority for IS researchers.

A second potential concern is that the dependent construct used here represents behavioral intent rather than actual payment system adoption, yet the latter is the real construct of interest. However, at the time of the study merchants were unable to formally adopt the new technology because the commercial launch of the smart card technology was to occur only after the termination of the market trial. All of the merchants surveyed in our study were actively participating in the test market and therefore had excellent opportunities to fully evaluate the smart card technology. Given this particular context, we believe that intention to adopt and actual adoption behavior are likely to be highly related to one another. Furthermore, other studies have demonstrated that the correlation between behavioral intent and subsequent behavior, while far from perfect, is often quite high (e.g., Sheppard et al. 1988). Thus, we suggest that in this case at least, intention to adopt is a reasonable proxy for actual adoption behavior.

Third, compared with previous adoption studies in IS, including the initial Moore and Benbasat (1994) empirical test of PCI, a wider variety of adoption antecedents had a significant influence on intention to adopt. It is likely that these results are due, in part, to the adoption setting used here. In our study, merchants were actively considering an innovation that required investments in assets, changes in business processes, and changes in the behaviors of checkout staff. In addition, adoption could also affect the perceptions and behaviors of those who interact with the organization (customers). This rich adoption context is not unlike many encountered by managers today (e.g., E-commerce, electronic data interchange). However, it is quite different from the research settings that have often been used to develop and test technology adoption models in the past. We believe that more research is needed to assess the size and nature of the impact of the empirical setting on study results since it seems plausible—based on the findings presented here—that research conducted in simplified adoption settings may lead to parsimonious models that miss much of the richness evident in more complex adoption settings.

A final limitation of the current study is that it is theoretically based solely on TRA. Some IS researchers prefer Ajzen's theory of planned behavior (or TPB, Ajzen 1991) to the theory of reasoned action because the former expands the latter by including perceived behavioral control (PBC). Furthermore, our use of TAM ignores the potentially important role that can be played by subjective norms (e.g., see Venkatesh and Davis 2000). Conceptually, these two additional constructs capture factors that might influence the adoption of an IS innovation in an organizational context. The subjective norm component represents a belief on the part of decision makers that people in relevant reference groups will expect them to use the innovation. This reference group might include corporate parents, competing businesses, friends, and business partners. Along similar lines, PBC represents decision-makers' beliefs that they can effectively operate or use an innovation should they choose to do so.

While the addition of these constructs can lead to superior model performance in some contexts, there are other situations where subjective norms and perceived behavioral control do not influence adoption intent or usage at all. For example, some studies that have modeled these constructs, expecting them to be significant in given empirical contexts, have achieved either weak or mixed results (e.g., Davis 1989, Mathieson 1991). Unfortunately, the current study did not include measures of either subjective norms or perceived behavioral control. Thus, it is not possible to examine whether or not these constructs affected merchants' decisions to adopt the smart card technology.

In a related vein, Venkatesh and Davis (2000) recently proposed an extended Technology Adoption Model (TAM2) that incorporates image and result demonstrability as precursors to perceived usefulness, but does not model their direct effects on intention.[11] One implication of this theoretical model is that whenever usefulness is found to have no significant impact on intention, the effects of image and demonstrability will by definition be irrelevant to intention. This perspective is at odds with the work of Agarwal and Prasad (1997), who found a significant and strong direct effect of demonstrability on intention, even after controlling for the effect of usefulness. Furthermore, both the current study and that conducted by Gagliardi and Compeau (1995) noted a significant relationship between image and intention even when usefulness (in the form of RA) was included as a separate predictor. The correlations that Venkatesh and Davis report between image and intention and between demonstrability and intention are also high; whether or not these effects disappear after controlling for the effect of usefulness is not clear.

Although the current study compares the predictive abilities of TAM and the PCI model, the collected data cannot be used to test the extended TAM2 model. We suggest that future work focused on determining whether usefulness is more correctly viewed as a mediator between other PCI characteristics and intention, or as simply one of many potential drivers of intention, should be seen as a high priority for IS researchers.

Conclusion

The current study directly compared the performance of the PCI belief constructs with those developed in TAM as part of an ongoing, naturally occurring, in-market test of an innovative retail technology. Although both sets of adoption antecedents did a good job of predicting merchants' intentions to adopt the new smart card technology, the PCI belief constructs significantly outperformed TAM. In addition, the descriptive richness of the information provided by the PCI constructs (in the form of estimated relationships between its antecedent constructs and intention to adopt) relative to the information provided by the TAM antecedents suggests strongly that IS researchers need to pay serious attention to model robustness, and not just parsimony, when specifying an appropriate model of the new technology adoption process.

[11]TAM2 also includes voluntariness as a moderator between subjective norm and intention.

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Appendix—Measures

Note: In each instance, the first item below is the operationalization used in our study. The italicized version which follows is the measure as it originally appeared in either Davis (1989) or Moore and Benbasat (1991), respectively.

TAM—Perceived Usefulness

(1) —Using the Exact card system enables me and my staff to process payments more quickly. *Using Chart-Master in my job would enable me to accomplish tasks more quickly.*

(2) —Using the Exact card system improves the job performance of me and my staff. *Using Chart-Master would improve my job performance.*

(3) —Using the Exact card system increases the productivity of me and my staff. *Using Chart-Master in my job would increase my productivity.*

(4) —Using the Exact card system enhances the on-the-job effectiveness of me and my staff. *Using Chart-Master would enhance my effectiveness on the job.*

(5) —Using the Exact card system makes it easier for me and my staff to do our jobs. *Using Chart-Master would make it easier to do my job.*

(6) —My staff and I find the Exact card system useful to us in our jobs. *I would find Chart-Master useful in my job.*

TAM—Perceived Ease-of-Use

(1) —Learning to operate the Exact card system was easy for me and my staff. *Learning to operate Chart-Master would be easy for me.*

(2) —My staff and I find it easy to get the Exact card system to

do what we want it to do. *I would find it easy to get Chart-Master to do what I want it to do.*

(3) —Using the Exact card system is clear and understandable for me and my staff. *My interaction with Chart-Master would be clear and understandable.*

(4) —My staff and I find the Exact card system to be flexible to use. *I would find Chart-Master to be flexible to interact with.*

(5) —It was easy for my staff and I to become skillful at using the Exact card system. *It would be easy for me to become skillful at using Chart-Master.*

(6) —My staff and I find the Exact card system easy to use. *I would find Chart-Master easy to use.*

PCI—Relative Advantage

Note: Several of the measures for TAM's Perceived Usefulness construct were either identical to or very similar to 3 of the 5 measures for the short-form scale items for Moore and Benbasat's Relative Advantage construct within the PCI model. As such, the 3 items in question were presented in their entirety in the TAM section of the survey (which appeared first). The responses to these 3 items were then used in conjunction with the 2 "PCI-specific" measures below to comprise the PCI Relative Advantage construct. Looking to TAM's Perceived Usefulness construct above, the 3 measures used to capture the overlapping items in PCI's Relative Advantage construct are TAM measures 1, 4, and 5, respectively.

(1) —Using the Exact card system improves the quality of the sales transactions my staff and I conduct in our business. *Using a PWS improves the quality of work I do.*

(2) —Using the Exact card system gives me and my staff greater control over our business' sales transactions. *Using a PWS gives me greater control over my work.*

PCI—Ease-of-use

Note: All four of the measures for the short-form PCI Ease-of-Use construct were captured either verbatim or very closely in parallel items in TAM's Perceived Ease-of-Use construct. As such, the 4 items in question were presented in their entirety in the TAM section of the merchant survey (which appeared first). The responses to these 4 items were then used to measure the PCI Ease-of-Use construct. Looking to TAM's Perceived Ease-of-Use construct, the 4 measures used to capture Ease-of-Use in PCI are TAM measures 1, 2, 3, and 6 above, respectively.

PCI—Compatibility

(1) —Using the Exact card system is compatible with all aspects of my business' sales transactions. *Using a PWS is compatible with all aspects of my work.*

(2) —I think that using the Exact card system fits well with the way my staff and I like to receive payment for goods and services. *I think that using a PWS fits well with the way I like to work.*

(3) —Using the Exact card system fits with our business' work style. *Using a PWS fits into my work style.*

PCI—Image

(1) —Merchants who use the Exact card system have more prestige than those who do not. *People in my organization who use a PWS have more prestige than those who do not.*

(2) —Merchants who use the Exact card system have a higher profile than those who do not. *People in my organization who use a PWS have a high profile.*

(3) —Having an Exact card system is a status symbol among the merchants I know. *Having a PWS is a status symbol in my organization.*

PCI—Result Demonstrability

(1) —My staff and I would have no difficulty telling others about our experience using the Exact card system. *I would have no difficulty telling others about the results of using a PWS.*

(2) —My staff and I could communicate to others the consequences of using the Exact card system. *I believe I could communicate to others the consequences of using a PWS.*

(3) —The impact of using the Exact card system is apparent to my staff and me. *The results of using a PWS are apparent to me.*

PCI—Visibility

(1) —In my community, I see many merchants using the Exact card system. *In my organization, one sees PWS on many desks.*

(2) —The Exact card system is not very visible in my community. *PWS are not very visible in my organization.*

PCI—Trialability

(1) —Before deciding whether to use the Exact card system, my staff and I were able to properly try it out. *Before deciding whether to use any PWS applications, I was able to properly try them out.*

(2) —My staff and I have had a great deal of opportunity to try the Exact card system in various situations. (e.g., a customer asks to pay for a purchase with a combination of Exact and cash). *I was permitted to use a PWS on a trial basis long enough to see what it could do.*

PCI—Voluntariness

(1) —My business' use of the Exact card system was voluntary. *My use of a PWS is voluntary (as opposed to required by my superiors or job description).*

(2) —Although suggested to my business, using the Exact card system was not compulsory. *Although it might be helpful, using a PWS is certainly not compulsory in my job.*

Intention to Adopt

(1) —Once the trial period is over, I will be interested in continuing to use a smart card payment system in my business.

(2) —Once the trial period is over, I will arrange to permanently adopt a smart card payment system as soon as possible.

(3) —Once the trial period is over, I won't see much need to continue to use a smart card payment system in my business.

(4) —Once the trial period is over, I will recommend that my fellow merchants get a smart card payment system.

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