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RESEARCH NOTE

Nonlinearities Between Attitude and Subjective Norms in Information Technology Acceptance: A Negative Synergy?[1]

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Abstract

Empirical results both from information technology acceptance research as well as from other fields suggest that attitude and subjective norms may have a nonlinear relationship. Based on the economic theory of complementarities, the present paper hypothesizes a substitution relationship or negative synergy between attitude and subjective norms in organizational IT use contexts. Employing two methods for modeling and measuring nonlinear effects of latent constructs, as well as two approaches for visualizing and interpreting interaction and quadratic terms, structural equation modeling analysis of data collected from 258 users of a variety of IT applications in 14 organizations provides support for the hypothesis that attitude and subjective norms were substitutes in predicting intention to use.

[1]Elena Karahanna was the accepting senior editor for this paper. Susan Brown served as the associate editor.

Keywords: IT acceptance, theory of complementarities, latent variable interactions, nonlinear modeling, structural equation modeling, quadratic latent variables, response surface methodology

Introduction

> "The simplest things are often the most complicated to understand fully"
> (Samuelson 1974)

Attitude and subjective norms are two key constructs of the theories of reasoned action (TRA) and planned behavior (TPB) (Ajzen 1991; Ajzen and Fishbein 1980), and the original formulations of these models or their derivatives have often been used to explain or predict acceptance of information technology (Benbasat and Barki 2007). While this research has advanced our understanding of how attitude and subjective norms influence IT acceptance, it has also largely overlooked the nonlinear relationships that can exist between key model constructs. Several considerations suggest the need to identify such relationships between attitude and subjective norms. First, the theoretical independence of attitude and subjective norms (i.e., additive relationship) is thought to oversimplify or misspecify the causal structure of their relationship and effect on behavioral intentions (Liska 1984). Second, nonlinear relationships among key constructs of both TRA and TPB were initially hypothesized (Ajzen 1991; Ajzen and Fishbein 1980), and have been observed in various non-IS contexts (e.g., Albarracín et al. 2005; Eagly and Chaiken 1993; Jonsson 1998; Ping 2004; Terry et al. 2000). Third, omitting nonlinear effects from research models tends to either understate or overstate the main effects, leading to erroneous, partial, or incomplete interpretations (Ping 2002). As such, uncovering the complex and contingent relationship between key constructs such as attitude and subjective norms can provide finer grained knowledge about the determinants of individual IT acceptance.

The present paper hypothesizes Edgeworth-Pareto substitutability (Samuelson 1974; Weber 2005) between attitude and subjective norms and tests their nonlinear effect on IT use intentions. Edgeworth-Pareto substitutability is defined as a situation where the combined effect of two factors is less than the sum of each factor's separate effect and can be viewed as negative synergy, that is, increasing either factor decreases the marginal impact of the other.[2] In contrast, complementarity or positive synergy reflects a situation where an increase in either factor increases the impact of the other. The study hypothesis was examined via structural equation modeling (SEM) analyses of data collected from 258 users of a variety of information systems and the results supported the hypothesized relationship. It is worth noting that the present paper provides the first evidence of a substitutive relationship between attitude and subjective norms. While past research has examined nonlinearities between these two constructs, only complementarity relationships have been observed in non-IS contexts (e.g., Bansal and Taylor 2002; Grube and Morgan 1990; Terry et al. 2000).

Nonlinearities Between Attitude and Subjective Norms

TRA and TPB posit that behavior is influenced by behavioral intention, which in turn is influenced by attitude toward and subjective norms concerning the behavior. While TRA assumed an additive relationship between these constructs, interaction effects were explicitly hypothesized in TPB (Ajzen 1991, p. 188) and observed in a variety of non-IS contexts. For example, Andrews and Kandel (1979) found that the attitude–subjective norms interaction (A*SN) was a strong predictor of "novel and shifting" behaviors in adolescent drug use, and Rabow et al. (1987) found strong support for A*SN in adult alcohol consumption. Likewise, Grube and Morgan (1990) proposed a contingent consistency hypothesis to support the significant A*SN observed concerning adolescent smoking, drinking, and drug use (the interactive TRA model was found to be a stronger predictor of behavior than the additive model). More recently, Terry et al. (2000) found that A*SN predicted behavior better, and Bansal and Taylor (2002) found that mortgage customers' switching behavior was influenced by A*SN. Thus, A*SN has been found positive and significant in a variety of non-IS contexts.

IS research has basically examined the linear effects of attitude and subjective norms on intentions and behaviors, with moderation effects of demographical characteristics being the only nonlinear relationships investigated. For example, Venkatesh et al. (2003) and Brown and Venkatesh (2005) studied age, sex, income, and marital status as moderators of the relationship between social influence and intention to adopt. To our knowledge, the present paper provides the first attempt to theorize a negative synergy between attitude and subjective norms.

Many organizations ask their employees to use certain organizational information technologies in their work such as intranets, group systems (e.g., Lotus Notes), or ERPs, but without forcing them to do so. In many such cases, individuals need to use these technologies for some of their work, but they also have discretion regarding the extent to which they will use the system's various functionalities and how much they will use the system in their different tasks. Thus, while employees may need to utilize the IT at a certain level for certain tasks, using the system is under their volitional control. In such contexts, a substitutability or negative synergy between attitude (i.e., the behavioral, cognitive belief) and subjective norms (i.e., the normative, external pressure[3]) seems plausible. For example, in the presence of strong subjective norms, usage intention is likely to be only marginally impacted by a more positive attitude (i.e., even though I think the system is poor, I still use it to accomplish some of my tasks because of organizational pressures). Alternatively, in the presence of strong positive attitude, usage intentions are likely to be marginally impacted by an increase in subjective norms (i.e., even though there is no organizational pressure for me to use the system, I use it because I think it is great. Hence, adding more pressure will have a decreasing impact on my usage intentions). These considerations suggest that, when individuals use organi-

[2]Note that Edgeworth-Pareto substitution is different from perfect substitution (e.g., tea and coffee) and compensated substitution (e.g., tea and coffee are compensated substitutes if a rise in the price of either tea or coffee increases demand for coffee or tea, respectively). Similarly, Edgeworth-Pareto complementarity is also different from perfect complementarity (e.g., right and left shoe), and compensated complementarity (e.g., tea and lemon are compensated complements if a rise in the price of tea reduces demand for lemon) (Samuelson 1974). The authors wish to thank an anonymous reviewer for suggesting that the Edgeworth-Pareto substitution effect be viewed and/or explained as negative synergy.

[3]As noted by Coleman (1990, p. 241) "a norm is a property of a social system, not of an actor within it."

zational IT to accomplish tasks, subjective norms are likely to act as a substitute for attitude in the former case and attitude is likely to act as a substitute for subjective norms in the latter. In other words, while both attitude and subjective norms are likely to have direct main effects on intention to use, their combined effect is likely to be inferior to the sum of their separate effects (i.e., an increase in subjective norms will reduce the marginal impact of an increase in positive attitude, and an increase in positive attitude will reduce the marginal impact of an increase in subjective norms).

Examples of negative synergistic relationship between behavioral and normative beliefs have also been noted in organizational settings. Fleming and Spicer (2003) discussed the case of "public relations firms hired by large petroleum companies to believe in the ethical propriety of their destructive oil explorations" (p. 170). While these firms may hold negative attitudes about defending their clients' image knowing the negative environmental effects of oil exploitation, they still perform their tasks because it is socially legitimate to honor a labor assignment with a company in good public standing. In such a case, the conflicting cognitive and normative forces would have a substitutive relationship since behavior will be marginally impacted by an increase in attitude given that such behavior is already influenced by the normative force which compensates for the weak cognitive force.[4]

Based on the preceding arguments, attitude and subjective norms were hypothesized to act as Edgeworth-Pareto substitutes in organizational IT use contexts where organizational pressures to use the system exist and users have volitional control over their usage of the system. Hence,

H_1: *The attitude–subjective norms interaction will negatively influence intention to use, indicating substitutability or negative synergy.*

[4]Another illustration of a substitutive relationship between attitude and subjective norms is the example of a McDonald's employee who wore a "'McShit' tee-shirt under her uniform in a clandestine fashion" to express her negative attitude toward the values "enshrined in the training programs" while still performing her tasks as an "efficient member of the team" (Fleming and Spicer 2003, p. 166). In this case, attempting to positively increase the employee's attitude is likely to only marginally improve the employee's performance of her tasks.

Modeling Nonlinearities Between Attitude and Subjective Norms with the Theory of Complementarities

The concept of complementarity posits that the influence of two complementary factors on a target factor is superior to the additive influence of each independent factor (Edgeworth 1897, in Weber 2005; Milgrom and Roberts 1995; Samuelson 1974). Two factors are said to be complements if their combined effect is superior to the sum of their separate effects. Similarly, two variables are said to be substitutes (or rivals) if their combined effect is less than the sum of their separate effects. In the same vein, two variables are said to be independent if their combined effect is equal to the sum of their separate effects (Samuelson 1974).

While the theory of complementarities (TC) was originally applied in economics to describe the complementarity between input factors, its properties have been extended to describe different organizational and individual phenomena.[5] For example, Leibenstein (1982) showed that individual effort choice within a firm (i.e., the level of effort exerted by an individual to accomplish his/her tasks) provided an optimized solution when peer group "effort convention," determined by perceived group pressures, substituted to one's individual "maximizing satisfaction option," producing an appropriate effort choice by the individual. Viewing group "effort convention" as subjective norms (i.e., perceived group pressures) and "individual maximizing satisfaction option" as attitude (i.e., individual evaluation of the consequences of performing a behavior), TC properties (i.e., the form of the interaction between variables) can be applied to individual IS usage in organizational settings.

The interaction method is considered to be one of the most reliable methods for measuring complementarities (Chin et al. 2003; Jaccard and Wan 1996; Ping 1998, 2004), and was used in the present study. If we consider the case of two factors X and Z influencing Y,

$$Y = f(X, Z, X*Z, \xi\ldots) \quad (1)$$

the corresponding regression equation is

$$Y = \alpha + \beta_1 X + \beta_2 Z + \beta_3 X*Z + \xi \quad (2)$$

where α represents the intercept, β_1 the coefficient of factor X, β_2 the coefficient of factor Z, β_3 the coefficient of the inter-

[5]Our review of 130 journals across 11 disciplines identified 156 empirical articles on complementarity, published between 1970 and 2006. This review is available from the authors.

action between factors X and Z, and ξ the residual term. Complementarity, substitution, or independence of factors X and Z are determined by the sign of the interaction coefficient, so that when

$\beta_3 > 0$; X and Z are complements (3)
$\beta_3 < 0$; X and Z are substitutes[6] (4)
$\beta_3 = 0$; X and Z are independent (5)

Most studies that have employed the interaction method have used standard or moderated regression (for a review of moderation effects, see Carte and Russell 2003) but the use of traditional regression for analyzing interaction effects has raised some objections (Carte and Russell 2003; Jaccard and Wan 1996; Ping 1996, 2002; Rigdon et al. 1998). When applied to continuous variables in survey data, traditional regression analysis yields erroneous results because the analysis excludes the error terms of the interacting factors (Ping 2004; Wood and Erickson 1998). As Jaccard and Wan (1996) noted, "The problem is that the measurement error (i.e., the e score) for a given product indicator must be a function of the measurement error of the component parts of the product term" (p. 54). Another limit of complementarity studies using the interaction method is that they rarely partial out the quadratic effects of the interacting variables. Yet, the omission of the quadratics creates fundamental limits regarding the significance and reliability of the hypothesized interactions (Carte and Russell 2003; Ping 2004). To overcome these limitations several methods have been proposed including those that are based on SEM.

Two points regarding the interaction method should be noted. First, there is general agreement that in most cases the "latent product is not a construct in the strict sense of the term. It *is* a variable that can suffer from measurement error [it shouldn't, therefore, be considered as] a psychological entity in and of itself" (Cortina et al. 2001, p. 328). However, latent product terms can indeed be modeled as constructs if supported by the underlying theory. Second, researchers have argued both for and against the appropriateness of using product terms with ordinal data (Rigdon et al. 1998; Russell and Bobko 1992), and some authors (Rigdon et al. 1998) view the use of a subsampling approach as a more accurate way of testing interactions with ordinal data. However, because this approach requires very large sample sizes (which are difficult to obtain in organization research), the use of product indicants in SEM is considered to be acceptable for ordinal data (Chin et al. 2003; Jaccard and Wan 1996; Ping 1998, 2004).

[6]Note that Edgeworth-Pareto substitution corresponds to β_1, $\beta_2 > 0$, and $\beta_3 < 0$.

Method

To test the study hypothesis, a questionnaire assessing the constructs of attitude, subjective norms, facilitating conditions, and intention to use was developed and distributed to 580 users of different information technologies in 14 organizations. Construct measures were adapted from Barki and Hartwick (1994), Taylor and Todd (1995), and Venkatesh et al. (2003) with all items assessed on 11-point Likert-type scales (0 to 10). A pretest of the questionnaire with seven IS professionals resulted in minor wording changes to some of the questions. Usable responses were obtained from 258 users (a 44.5 percent response rate). For statistical analysis, missing data were handled through list-wise deletion. As shown in Table 1, fourteen institutions from a variety of industries were represented in the sample. Thus, even though the sampling approach used was not random, the variety of the sample in terms of industry, organizations, and IT surveyed were considered adequate for the purposes of the present study.

As shown in Table 2, a preliminary psychometric assessment of the survey instrument indicated that all values were above acceptable standards. A confirmatory factor analysis (CFA) with LISREL v. 8.72 was performed next. Following SEM estimation recommendations (Byrne 1998; Im and Grover 2004) the covariance matrices of observed variables were used as input. Analysis of the traditional linear TRA/TPB[7] based model yielded good fit indices for the measurement

[7]Given the formative nature of the intention to use items, this construct was modeled with a single reflective indicator computed as the mean of its six items. The authors wish to thank an anonymous reviewer for bringing up this point. However, "zero" answers to the formative items of intention to use can have two meanings: (1) that the task in question is relevant for the respondent but he/she intends to make no use of the system for that task, or (2) that the task is irrelevant for the respondent. In the first instance, intention needs to be calculated by averaging all six items of the scale, regardless of whether one or more items were scored zero. This was done and yielded a sample of N = 230. In the second instance, the calculation of intention needs to exclude items with zero scores (since they are irrelevant, their inclusion in the average lowers the average intention score to a value below its "true" average). As we could not determine whether zero scores meant "relevant but no use" or "irrelevant," we created a "guaranteed relevance for all intention items" subsample by selecting only the respondents who had scored all intention items greater than 0. As such, the subsample (N = 164) eliminated the potential ambiguity of zero responses in the N = 230 sample. The samples of N = 230 and N = 164 are the two extremes. In reality, the truth is somewhere in between where some respondents scored a zero for tasks not relevant and others scored a zero for tasks for which they did not intend to use the system. If results converged at these two extremes, then the interpretation of what "zero" means is likely immaterial to the results. All models were tested with both samples, and yielded highly convergent results showing substitution between A*SN. As an additional test, all models were also tested with intention measured via a single, global reflective item (N = 233) (*"When you perform a task that you know the system supports, what percentage of time do you intend to use the system?"*) and once again yielded similar results to those obtained with N = 230 and N = 164, providing evidence for the stability and robustness of the substitutive relationship observed between attitude and subjective norms.

Table 1. Sample Distribution

Industry	N	%	Industry	N	%
Printing and Publishing	125	48.5	Transport	6	2.4
Agriculture	3	1.0	Telecommunications	10	4.0
Furniture	2	0.7	Lotteries	32	12.3
Finance	53	20.5	Other (government agencies)	27	10.6
			Total	258	100

Table 2. Measures

	Reliability	Loadings	Means/ St. Dev.	Scale
Attitude All things considered, using the system is a… • foolish move — wise move (x_1) • negative step — positive step (x_2) • ineffective idea — effective idea (x_3)	α = 0.96	.923 .959 .935	6.917/3.122	(0–10)
Subjective Norms • People who are important to me think that I should use the system (x_4) • People who influence me think that I should use the system (x_5)	α = 0.96	.944 .935	6.954/2.952	(0–10) Disagree completely to Agree completely
Facilitating Conditions • I have the human and technological resources necessary to use the system (x_6) • I have the knowledge necessary to use the system. (x_7) • A specific person (or group) is available for assistance with system difficulties (x_8)	α = 0.74	.851 .808 .752	7.659/1.946	(0–10) Disagree completely to Agree completely
Intention to Use (formative construct) y_1 = mean of 6 items) I intend to continue using this system to… • solve various problems • justify my decisions • exchange with other people • plan or follow-up on my tasks • coordinate with others • serve customers	NA	NA	6.04/2.580	(0–10) Not at all to Very much

model. Factor loadings were all above 0.75, providing evidence of convergent validity and internal consistency.

Discriminant validity between attitude and subjective norms and facilitating conditions was assessed by examining whether their correlations were significantly different from unity (Jiang et al. 2002). To do so, the significance of chi-square differences was examined between an unconstrained model (all three latent constructs of attitude, subjective norms, and facilitating conditions correlating freely) and three constrained models (where pair wise correlations between the three constructs, i.e., A-SN, A-FC, and SN-FC, were each fixed to one). The chi-squares of the constrained models ($\Delta\chi^2 = 32.12$, df = 1, $p < 0.005$, $\Delta\chi^2 = 26.16$, df = 1, $p < 0.005$, $\Delta\chi^2 = 22.18$, df = 1, $p < 0.005$, respectively) were significantly higher than that of the unconstrained model indicating that the latter fitted the data better, providing evidence of discriminant validity. In addition, the square root of all AVEs (average variance extracted) were larger than interconstruct correlations (shown in Appendix A), and all construct indicators loaded on their corresponding construct more strongly than on other constructs, providing further evidence of discriminant validity (Chin 1998).

Table 3. Comparison of the Linear and Nonlinear Models

Indices	Linear Model	Nonlinear Model (with interactions only)	Single-Indicator Nonlinear Model	Multiple-Indicator Nonlinear Model
χ^2 (df; p value)	38.04 (22; 0.018)	85.49 (50; 0.00)	139.19 (69; 0.00)	596.58 (244; 0.00)
NFI	0.97	0.94	0.92	0.90
IFI	0.99	0.98	0.95	0.93
CFI	0.99	0.98	0.95	0.93
GFI	0.96	0.94	0.91	0.81
RMSEA	0.056	0.056	0.067	0.079
R^2 (Intention to Use)	25%	32%	35%	33%
ΔR^2	—	7%	10%	8%

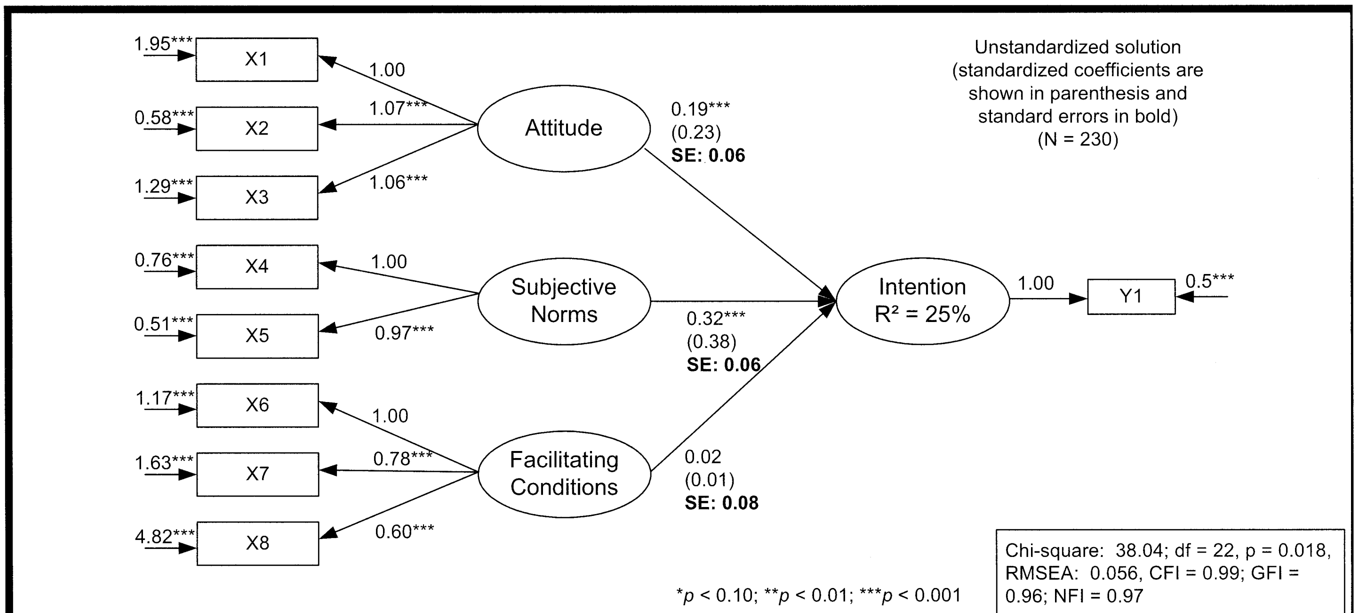

Figure 1. The Linear Model

Following Ping (1995, 1998, 2004), the validity and stability of the linear model was established first, prior to the estimation of the nonlinear model with interactions and quadratics. Estimation results of the linear structural model are shown in Figure 1.

To assess method bias, a first-order latent method factor was added to the reflective model of Figure 1 with all construct items modeled as indicators of the method factor (Podsakoff et al. 2003). As shown in Figure 2, the fit indices of the model including the method factor were not significantly better than those of Figure 1 (χ^2 = 31.96; df = 18; p = 0.022; RMSEA = 0.058; $\Delta\chi^2$ = 6.08, df = 4, ns; AVE of method factor = 0.24). In addition, the structural coefficients of the model as well as the factor loadings of attitude, subjective norms, and intention to use remained significant despite the inclusion of common method effects, suggesting that method bias is unlikely to have significantly affected the study results (Conger et al. 2000).

Estimation of the Nonlinear Model

Based on the interaction method of assessing nonlinearities, two quadratic nonlinear SEM were estimated. The first model applied Kenny and Judd's (1984) full set of unique nonlinear

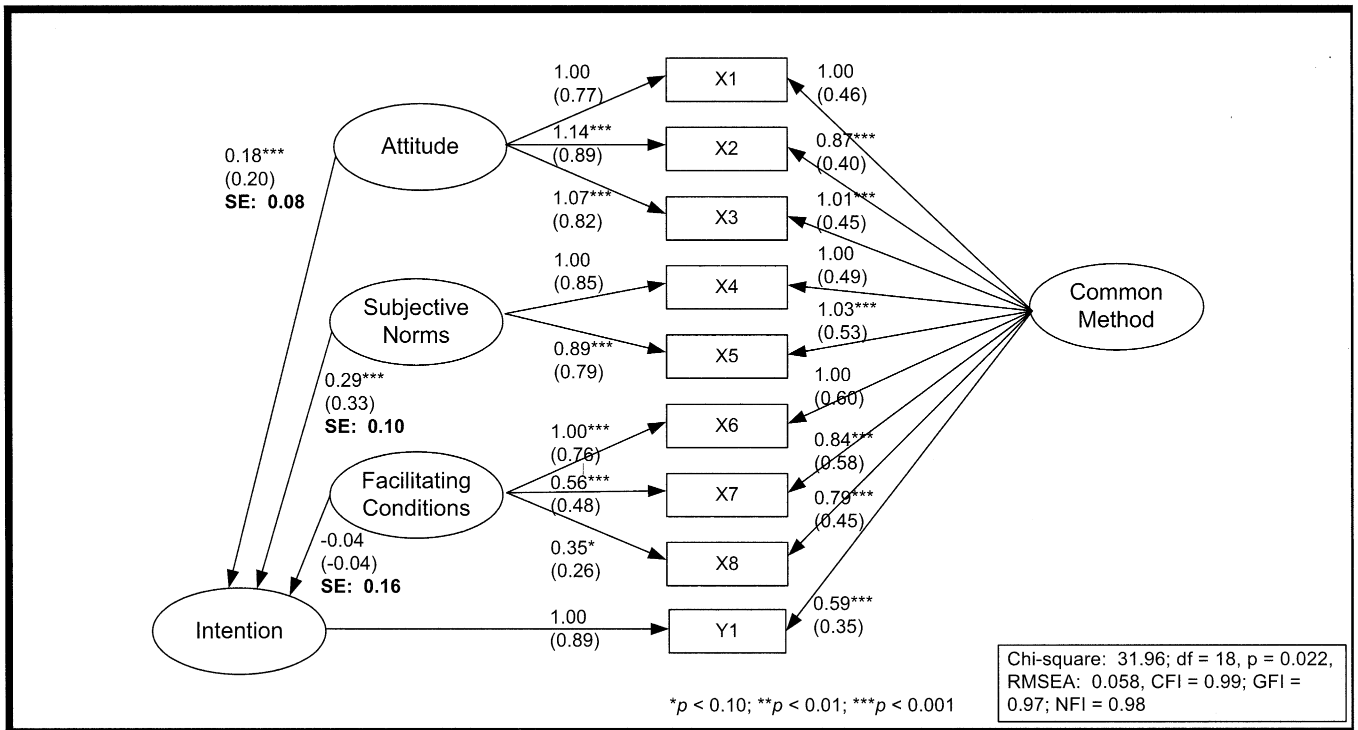

Figure 2. Assessment of Common Method Variance

cross-product terms, and the second used Ping's (1995, 1996, 2004) single nonlinear product terms. The structural equations of the multiple and single indicator models are given by

$$\eta_1 = \gamma_1\xi_1 + \gamma_2\xi_2 + \gamma_3\xi_1\xi_2 + \gamma_4\xi^2{}_1 + \gamma_5\xi^2{}_2 + \zeta_1 \quad (6)$$

The two-step procedure recommended by Ping was followed to assess these models. First, *a priori* factor loadings and error terms were computed, and then the nonlinear constraints were entered. With X and Z representing attitude and subjective norms respectively, the nonlinear models must satisfy the following constraints (Jaccard and Wan 1996; Kenny and Judd 1984; Ping 1996):

- Variances of the nonlinear indicators (interaction) such as x_1z_1 will be given by
  $$Var(x_1z_1) = \lambda_{x1}{}^2\lambda_{z1}{}^2[Var(X)Var(Z) + Cov^2(X,Z)] + \lambda_{x1}{}^2Var(X)Var(\varepsilon_{z1}) + \lambda_{z1}{}^2Var(Z)Var(\varepsilon_{x1}) + Var(\varepsilon_{z1})Var(\varepsilon_{x1}) \quad (7)$$

- Loadings of the nonlinear indicators (interaction) will be given by
  $$\lambda_{x1z1} = \lambda_{x1}\lambda_{z1} \quad (8)$$

- Error variances of the nonlinear indicators (interaction) will be given by
  $$Var(\varepsilon_{x1z1}) = \lambda_{x1}{}^2Var(X)Var(\varepsilon_{z1}) + \lambda_{z1}{}^2Var(Z)Var(\varepsilon_{x1}) + Var(\varepsilon_{z1})Var(\varepsilon_{x1}) \quad (9)$$

- Variances of the nonlinear indicators (quadratic) will be given by
  $$Var(x_1x_1) = 2\lambda_{x1}{}^2\lambda_{x1}{}^2Var^2(X) + 4\lambda_{x12}Var(X)Var(\varepsilon_{x1}) + 2Var(\varepsilon_{x1})^2 \quad (10)$$

- Loadings of the nonlinear indicators (quadratic) will be given by
  $$\lambda_{x1x1} = \lambda_{x1}\lambda_{x1} \quad (11)$$

- Error variances of the nonlinear indicators (quadratic) will be given by
  $$Var(\varepsilon_{x1x1}) = 4\lambda_{x1}{}^2Var(X)Var(\varepsilon_{x1}) + 2Var(\varepsilon_{x1})^2 \quad (12)$$

In addition to these nonlinear constraints, estimation of interaction and quadratic terms requires mean centering of the data (Jaccard and Wan 1996; Ping 2004) in order to reduce latent variable multicollinearity, and to avoid biased estimates of structural coefficients (Cortina et al. 2001; Jaccard and Wan 1996; Ping 2004; for an opposing view regarding the role of mean centering on collinearity reduction, see Brambor et al. 2006). Further, since product indicators share components with their constituent factors, error terms may be allowed to correlate freely (Jaccard and Wan 1995; 1996; Ping 2004). Finally, note that as hypothesized by the TC, the interaction patterns are given by the Gamma (γ) coefficients as follows:

$$\gamma > 0;\ XZ \text{ are complements} \quad (13)$$
$$\gamma < 0;\ XZ \text{ are substitutes} \quad (14)$$
$$\gamma = 0;\ XZ \text{ are independent} \quad (15)$$

The Multiple-Indicator Nonlinear Model

Following Kenny and Judd (1984), all possible cross-products were formed with the indicators involved in the interaction. The full set of products were used by multiplying each attitude indicator with the subjective norms indicator for the interaction terms, as well as each "within" factor indicator for the quadratic terms as follows:

$$A{*}SN = (x_1z_1 + x_1z_2 + x_2z_1 + x_2z_2 + x_3z_1 + x_3z_2) \quad (16)$$
$$A{*}A = (x_1x_1 + x_1x_2 + x_1x_3 + x_2x_2 + x_2x_3 + x_3x_3) \quad (17)$$
$$SN{*}SN = (z_1z_1 + z_1z_2 + z_2z_2) \quad (18)$$

As shown in Figure 3, this resulted in six indicators for A*SN, six indicators for the quadratic attitude term, and three indicators for the quadratic subjective norms term. Loadings and error terms for each indicator were then computed according to the nonlinear equations (7) to (12), and used as fixed values in the LISREL estimation procedure, and the variances of nonlinear factors were entered as fixed values (Ping, 2004). Using a two-step approach such as this one is valuable because of sample size considerations (Cortina et al. 2001), since providing initial estimation values to LISREL decreases the probability of Type I and II errors by keeping the number of freely estimated parameters below the number of distinct elements in the input variance–covariance matrix (Im and Grover 2004).[8]

As shown in Table 3, initial fit statistics of the nonlinear multiple-indicator measurement model were acceptable. Estimation results of the nonlinear multiple-indicator structural model are shown in Figure 3. As hypothesized, A*SN was significant and negative ($\gamma_3 = -0.04$, $p < 0.\ 001$), indicating substitution between attitude and subjective norms.

[8]Statistical power could be "unaltered by the introduction of interactions and/or quadratics because in factored coefficients the interactions/quadratics capture the statistical power of the unfactored coefficients" (Ping 004, p. 7).

The Single-Indicator Nonlinear Model

Following Ping (1996, 2004), A*SN was obtained by computing the sums of each factor's indicators followed by the product of these sums. That is,

$$A{*}SN = (x_1+x_2+x_3) * (z_1 + z_2) \quad (19)$$
$$A{*}A = (x_1+x_2+x_3) * (x_1+x_2+x_3) \quad (20)$$
$$SN{*}SN = (z_1 + z_2) * (z_1 + z_2) \quad (21)$$

Loadings and error terms for the product indicators were then computed according to the nonlinear constraints of equations (7) to (12) and entered as fixed values in the model (Ping 1996, 2004). As shown in Table 3, fit statistics of the single-indicator measurement model were acceptable. Figure 4 shows the estimation results of the single-indicator nonlinear model.

Similar to the results obtained for the multiple-indicator nonlinear model, the A*SN term was significant and negative ($\gamma_3 = -0.04$, $p < 0.001$), supporting H_1 and indicating substitution between attitude and subjective norms.

Comparative Assessment of the Linear and Nonlinear Models

The fit statistics of the linear model and the two nonlinear models (with quadratics) are provided in Table 3. As can be seen, all three models had good fit indices. As recommended by Carte and Russell (2003), a ΔR^2 test was performed between the linear model and the two nonlinear models. As shown in Table 3, the two nonlinear models explained a significantly greater proportion of the variance in intention to use than the linear model (33 percent and 35 percent versus 25 percent), indicating that the inclusion of A*SN significantly improved the prediction of intention to use.

Excluding quadratic terms from an analysis of nonlinear relationships can yield unreliable, biased, and/or erroneous results (Carte and Russell 2003; Jaccard and Wan 1996; Ping 2002; Rigdon et al. 1998). To investigate whether the inclusion of the quadratic terms inflated or suppressed the interaction, a model that included the A*SN term, but excluded the quadratic terms A*A and SN*SN, was estimated. As shown in Table 3 and Figure 5, this model had good fit parameters and the A*SN term was significant, indicating that the interaction was not spurious and that quadratic terms did not inflate its significance and reliability (Carte and Russell 2003; Ping 2004; Venkatraman 1989). A quadratic only model (without interactions) was also estimated to compare the ex-

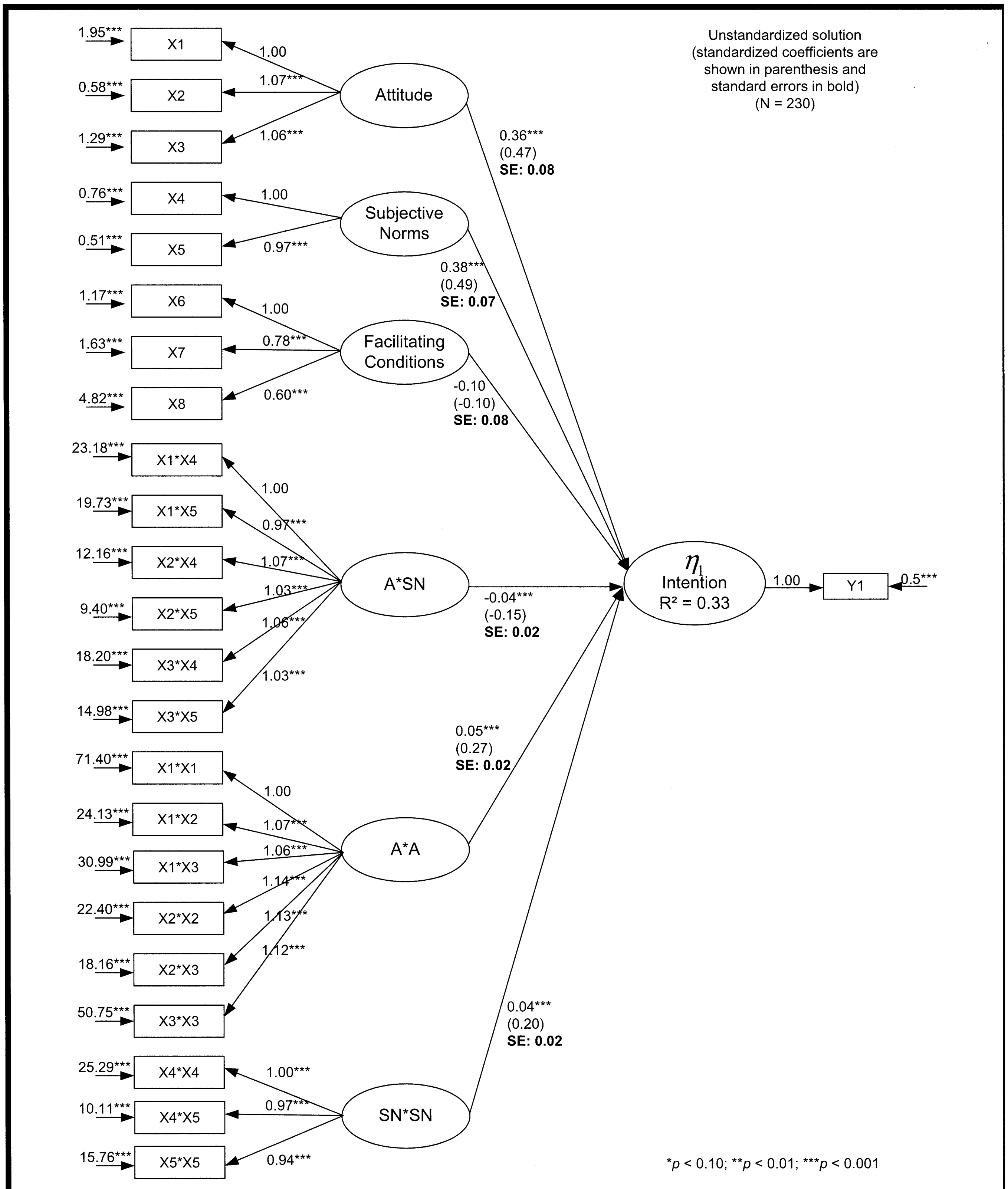

Figure 3. The Multiple-Indicator Nonlinear Model

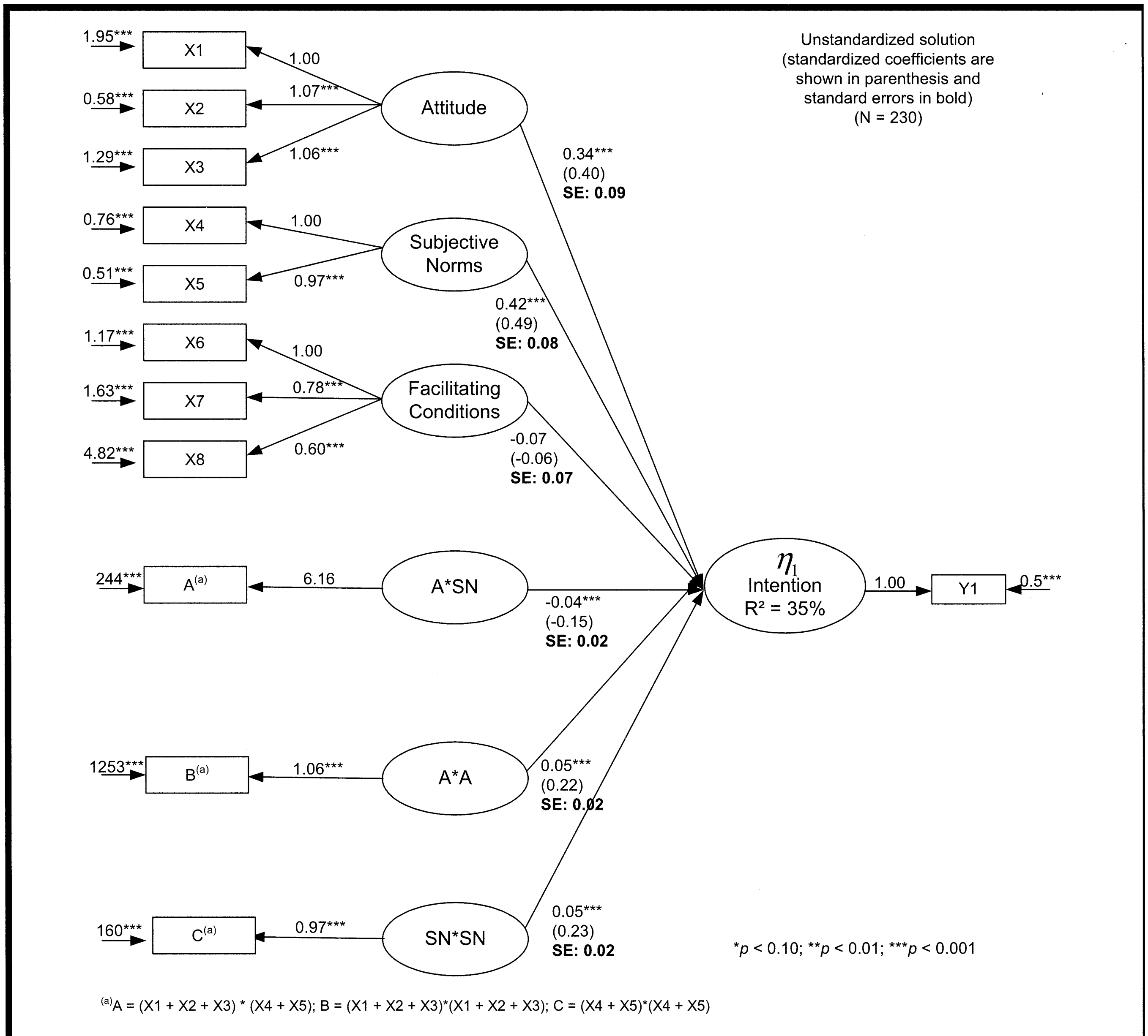

Figure 4. The Single-Indicator Nonlinear Model

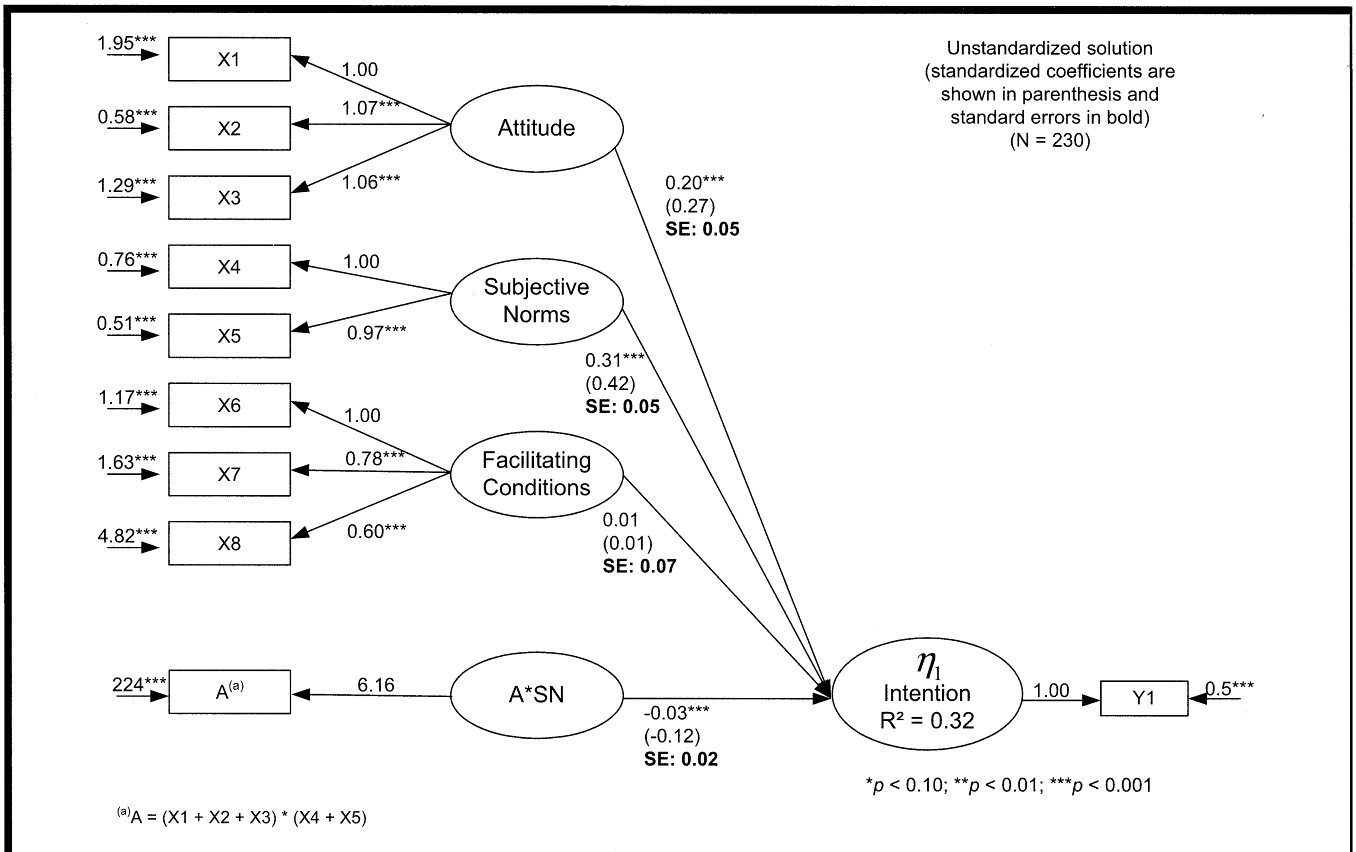

Figure 5. The Single-Indicator TPB-Based Model with Interactions, but Without Quadratics

planatory power of different models. The quadratic only model did not explain more variance ($\chi^2 = 116.73$; df = 59; p = 0.000; RMSEA = 0.065; $R^2 = .30$) than the models in Figures 3, 4, and 5, further supporting the robustness of the negative A*SN term.

Interpreting and Visualizing Nonlinear Effects

The attitude–subjective norms interaction was interpreted via the Ping (2004) procedure and Response surface methodology (Edwards and Parry 1993; Khuri and Cornell 1987).

The Ping Procedure

Ping's (2004) method for interpreting interactions and quadratics is based on the analysis of the factored coefficients or partial derivatives (Schoonhoven 1981) of the latent variables involved in a significant nonlinear relationship. Consider the structural equation of Figure 5:

$$\text{Intention to Use} = 0.20A + 0.31SN + 0.01FC - 0.03A*SN \qquad (22)$$

According to the procedure, when an interaction term is significant, the factored coefficient is used to represent the slope of the regression line of one of the independent variables with the dependent variable, while holding the other independent variable constant. In other words, if $I = \beta_1 A + \beta_2 SN + \beta_3 FC + \beta_4(A*SN)$, then $C_{SN} = (\beta_2 + \beta_4 A)$ shows the relationship between SN and Intention holding A and FC constant and represents the partial derivative of I with respect to SN ($dI/dSN = \beta_2 + \beta_4 A$). Similarly, $C_A = (\beta_1 + \beta_4 SN)$ shows the variation of A's influence on I with SN and FC constant, that is, the partial derivative of I with respect to A ($dI/dA = \beta_1 + \beta_4 SN$).

Analyzing the factored coefficients will hence lead to different interpretations of the SN→Intention and A→Intention associations than will the coefficients of A and SN in equation (22). For example, by considering the significance of β_1 and β_2 in (22), one could infer that A and SN were always posi-

Table 4. SN-I Relationship at Different Levels of A (Based on Figure 5: I = 0.20A + 0.31SN + 0.01FC – 0.03A*SN)

A	Coef SN	SE	t-value
10	0.218	0.193	1.13
9	0.248	0.174	1.42
8	0.278	0.155	1.79
7	0.308	0.136	2.26
6.9169	0.310	0.134	2.31
6	0.338	0.117	2.88
5	0.368	0.099	3.69
4	0.398	0.083	4.81
3	0.428	0.067	6.34
2	0.458	0.055	8.27
1	0.488	0.049	9.99
0	0.518	0.050	10.35

Coef SN = (.31 – .03A) (with A mean centered).

SE (Standard Error of Coef SN) = *Sqrt*(Var(β_{SN}) + A^2Var(β_{ASN}) + 2ACOV(β_{SN}, β_{ASN}).

Table 5. A-I Relationship at Different Levels of SN (Based on Figure 5: I = 0.20A + 0.31SN + 0.01FC – 0.03A*SN)

SN	Coef A	SE	t-value
10	0.109	0.193	0.56
9	0.139	0.174	0.80
8	0.169	0.155	1.09
7	0.199	0.136	1.46
6.954	0.200	0.135	1.48
6	0.229	0.117	1.95
5	0.259	0.099	2.60
4	0.289	0.083	3.49
3	0.319	0.067	4.73
2	0.349	0.055	6.30
1	0.379	0.049	7.76
0	0.409	0.050	8.17

Coef A = (.20 – .03SN) (with SN mean centered).

SE (Standard Error of Coef A) = *Sqrt*(Var(β_A) + SN^2Var(β_{ASN}) + 2SNCOV(β_A, β_{ASN}).

tively associated with Intention to Use. However, it would be misleading to overlook the information contained in the significant A*SN term. Indeed, while β1 and β2 may be significant, the factored coefficients of SN and A (i.e., $C_{SN} = \beta_2 + \beta_4 A$, and $C_A = \beta_1 + \beta_4 SN$) could be non-significant for some values of A and SN, respectively, or could be positive and then negative for some values of A and SN, as shown in Tables 4 and 5.

Based on equation (22), the factored coefficients (i.e., partial derivatives) of A and SN were calculated. As shown in Table 4, the influence of SN on intention is reduced when A increases, indicating a substitution effect of A. Similarly, as shown in Table 5, the influence of A on intention is reduced when SN increases, indicating a substitution effect of SN.

Response Surface Methodology

Response surface methodology (Edwards and Parry 1993; Khuri and Cornell 1987) is a procedure used to describe and visualize surface characteristics of full quadratic equations. Consider the structural equation of Figure 4:

$$\text{Intention to Use} = 0.34A + 0.42SN - 0.07FC - 0.04A*SN + 0.05A*A + 0.05SN*SN \quad (23)$$

The response variable corresponds to the dependent variable in equation (23) and is considered to be affected by the different levels of the independent factors of the equation (i.e., A, SN, FC, A*SN, A*A, and SN*SN). Using Design Expert (v. 7.1.2, 2007), a 3D visualization (Figure 6) of the relationships between attitude, subjective norms, and intention to use was obtained. To formally analyze the response function, three key features of the surface were computed (Table 6), the stationary point which "corresponds to the overall minimum, maximum or saddle point of the surface," as well as the first and second principal axis which "run perpendicular to one another and intersect at the stationary point" (Edwards and Parry 1993, p. 1583). To interpret the results, the procedure suggested by Edwards and Parry was followed by computing the intercepts and slopes of the principal axis and those of the Y = X and Y = -X lines.

The surface is slightly convex with its stationary points $X_0 = -4.06$ and $Y_0 = -5.01$ lying outside the near corner of the surface. The slopes of the first and second principal axes did not differ from -1 and 1 respectively, indicating no rotation off the Y = -X and Y = X lines. The surface shows that:

(1) When SN is high, the influence of A on intention to use is reduced. The slope of the bottom left edge of the surface is steeper than the slope of its top right edge, indicating that the influence of SN on intention to use is stronger when A is low than when it is high (i.e., indicating that SN substitutes for A).

(2) When A is high, the influence of SN on intention to use is also reduced. As shown by the steeper slope of the bottom right edge of the surface (compared to the slope of the top left edge), the impact of A on intention to use is higher when SN is low than when it is high, indicating that A substitutes for SN.

Discussion

The present study hypothesized and observed a substitutive relationship or negative synergy between attitude and subjective norms in organizational IT use contexts where organizational pressures to use the system exist and users have volitional control over their usage of the system. The study found that when subjective norms were high, increases in attitude had a decreasing marginal impact on IT use intentions, and when attitude was high, increases in subjective norms had a decreasing marginal impact on usage intentions. Also, the marginal influence of subjective norms on IT use intention was slightly higher than the marginal influence of attitude. That is, increasing SN while holding A constant produced a slightly higher intention value than increasing A while holding SN constant. Moreover, the two nonlinear models with the quadratic terms (the multiple indicator and single indicator models) explained more variance in intention to use than the linear model (8 percent and 10 pecent, respectively), and the nonlinear model without the quadratic terms (7 percent). Also, the quadratic only model without interactions did not explain more variance than the models of Figures 3, 4, and 5, indicating the robustness of the substitution relationship between A and SN.

The present study provides several contributions. Theoretically, the Edgeworth-Pareto substitution relationship between attitude and subjective norms provides a clearer picture of the relationship between these two constructs and their influence on IT use intentions in individual IT acceptance contexts. For example, as shown by the factored coefficients (partial derivatives) in Tables 4 and 5, the significance of the A→I and/or SN→I relationships actually vary according to the different levels of A and SN. This means that simply looking at the results of the linear model in Figure 1, one could mistakenly conclude that both attitude and subjective norms are always significantly related to IT use intention. On the other hand, taking the substitution relationship between these two constructs into account, it is seen that their impact on IT use intention is different depending on the level of each construct.

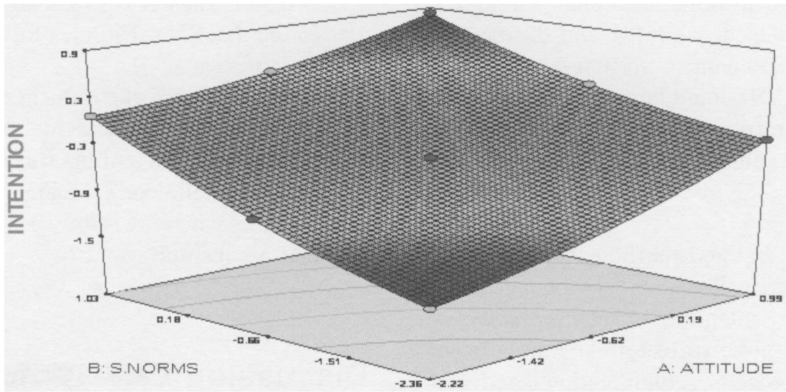

Figure 6. 3D Representation of the Significant Interaction and Quadratic Effects (Single-Indicator Model)

Table 6. Stationary Point and Principal Axis for Equation: I = 0.34A + 0.42SN – 0.07FC – 0.04A*SN + 0.05SN*SN

Stationary Point		Formulas*	First Principal Axis**		Formulas*	Second Principal Axis**		Formulas*
X_0	Y_0	$X_0 = \beta_2 \beta_4 - 2\beta_1\beta_6 / 4\beta_5\beta_6 - \beta_3^2$	P_{10}	P_{11}	$P_{11} = \beta_6 - \beta_5 + ((\beta_5\beta_6)^2 + \beta^2{}_3)^{½}$	P_{20}	P_{21}	$P_{21} = \beta_6 - \beta_5 - ((\beta_5\beta_6)^2 + \beta^2{}_3)^{½} / \beta_3$
-4.06	-5.01	$Y_0 = \beta_1 \beta_3 - 2\beta_2\beta_5 / 4\beta_5\beta_6 - \beta_3^2$	-9.07	-1.00	$P_{10} = Y_0 - P_{11}X_0$	-0.95	1.00	$P_{20} = Y_0 - P_{21}X_0$
The slopes and curvatures along the Y = X and Y = -X lines are respectively ($\alpha_x = 0.76$***, $\alpha_{x2} = 0.06$) and ($\alpha_x = 0.08$, $\alpha_{xx} = 0.14$***).			α_x	α_{x2}	$\alpha_x = \beta_1 + \beta_2P_{11} + \beta_3P_{10} + 2\beta_6P_{10}P_{11}$	α_x	α_{x2}	$\alpha_x = \beta_1 + \beta_2P_{21} + \beta_3P_{20} + 2\beta_6P_{20}P_{21}$
			0.79***	0.14	$\alpha_{x2} = \beta_5 + \beta_3P_{11} + \beta_6P^2{}_{11}$	0.70***	0.06	$\alpha_{x2} = \beta_5 + \beta_3P_{21} + \beta_6P^2{}_{21}$

- The Y = X line runs diagonally from the near corner to the far corner of the plane, and the Y = -X line runs diagonally from the left to right. The first and second principal axes are perpendicular and intersect at the stationary line.
- The slope along the Y = X line is given by $\alpha_x = \beta_1 + \beta_2$ and its curvature by $\alpha_{x2} = \beta_3 + \beta_4 + \beta_5$. For Y = -X line $\alpha_x = \beta_1 - \beta_2$ and $\alpha_{x2} = \beta_4 - \beta_3 + \beta_5$.

*Based on Edwards and Parry (1993) and Kuhri and Cornell (1987).
**Standard errors for first and second principal axis were computed based on Oh and Pinsonneault (2007,pp. 265-265).
***$p < 0.005$

Thus, the results of the present study highlight the importance of including significant nonlinear relationships in research models in general, and taking into account the significant nonlinear relationship between A and SN in organizational IT use contexts in particular.

A related issue concerns the relative importance of the standardized coefficients of the interaction and quadratic terms. While it may be tempting to compare their respective impact on a study's dependent variable to assess their contribution, researchers warn against the interpretation of beta weights when interactions and quadratics are involved as these can be misleading (Carte and Russell 2003). Also, interpretation of significant nonlinear terms is suggested only if sustained by substantive theory (Shepperd 1991). Given that multiple nonlinear forms are possible for A and SN (e.g., A*SN*SN, A*A*A, $A^{1/2}$), the present paper represents only a first step toward the development of substantive theory regarding the nonlinear relationship between A and SN in IT use contexts. As such, it would not be appropriate to interpret the magnitudes of the A*SN, A*A, and SN*SN standardized coefficients of the present study. However, the fact that the standardized coefficients of all three terms were significant can serve to conclude that the substitution effect observed between A and SN was significant, suggesting the need for its inclusion in research models investigating organizational IT use contexts that are similar to that of the present study. As well, the presence of significant quadratics and interactions encourages further investigation via the conceptualization of higher order terms, and the results of the present study suggest this to be a potentially useful avenue for future research.

The results of the study can also shed additional light on some of the past results obtained in IT acceptance research and indicate that explicitly modeling the interaction term between attitude and subjective norms is likely to explain a larger percentage of the variance in IT use intentions. In addition, the present paper's development and operationalization of a complete nonlinear SEM that includes the interaction and quadratic terms provides a methodological contribution, overcoming the shortcomings of past research that has examined nonlinear relationships via more limited approaches (Carte and Russell 2003; Ping 2004; Venkatraman 1989).

The results of the present study also point to the importance of taking contextual differences into account when investigating research models that incorporate attitude and subjective norms. For example, Bansal and Taylor (2002) observed a positive interaction term between attitude and subjective norms, indicating Edgeworth-Pareto complementarity or positive synergy between these two constructs. However, as Bansal and Taylor did not include quadratic terms in their analysis, it is difficult to conclude about the significance of the interaction they observed or its direction (Ping 2004). On the other hand, an alternative explanation of Bansal and Taylor's results can perhaps be found in the non-organizational context of their study, which examined volitional mortgage switching behaviors where the relationship between attitude and subjective norms may indeed be very different than the organizational IT use context of the present study. It is also possible that the substitution relationship observed here between attitude and subjective norm may not apply to different organizational IT use contexts (e.g. contexts where usage is completely volitional).

On practical grounds, and given the prevalence of large organizational IT such as intranets and ERPs, the findings of the present study are likely to be applicable to a large number of IT use contexts. The finding that attitude and subjective norms exhibit a negative synergy indicate that high levels of subjective norms can have a positive effect on intentions to use an IT by compensating for weak attitudes, or alternatively that strong attitudes can compensate for the effect of low subjective norms. Practitioners can use this finding to gain greater insight into the relative influence of attitudinal and normative beliefs (and their antecedents) on implementation outcomes and can make more informed decisions regarding how much effort to invest in order to make attitudinal beliefs more positive or whether or not to foster the development of strong subjective norms.

Some limitations of the present study need to be acknowledged. First, the paper hypothesized only one nonlinear effect (i.e., the substitution between A*SN) in TRA/TPB-based models. Other nonlinear relationships between TPB constructs, such as positive A*FC or SN*FC interactions, have been observed in other contexts (e.g., Bansal and Taylor 2002). In addition, the potential moderating effects of demographical variables on SN and FC were not examined as they were beyond the scope of this paper. It is hoped that future research will theorize and test such relationships in IS contexts.

Second, although the sample size of the study is reasonable, the number of organizations involved in the research remains relatively small (i.e., 14). The present study's results would therefore need to be replicated with a larger sample of organizations. Third, while the measurement of complementarities with ordinal data is based on sound conceptual and mathematical grounds (Jaccard and Wan 1995, 1996; Ping 1996, 1998, 2002, 2004), further research is needed to assess the reliability of the product indicant techniques used here by comparing them to a subsampling approach (Rigdon et al. 1998). Moreover, although facilitating conditions were modeled as a reflective construct, it could be argued that a formative conceptualization would be more appropriate. FC could not be modeled as a formative construct because general reflective items for FC were not available to help with the identification problem that occurs when it is modeled as a formative construct (Jarvis et al. 2003). As a partial check, all models were also analyzed with FC measured via a single reflective item calculated as the mean of its three indicators (as was earlier done for intention to use). The results obtained were similar to those reported above, providing further evidence for their robustness. Finally, while method bias is unlikely to have affected the study's results (see Figure 2), the measurement of FC could contain some weaknesses as shown by the relatively weak (but significant) loadings of the trait factor as compared to the method factor, suggesting the need to test the validity of the A*SN negative synergy with better measures of FC.

Conclusions

The present paper was motivated by the premise that attitude and subjective norms exhibit a relationship that is neither additive nor complementary in organizational use contexts. As hypothesized, the study found an Edgeworth-Pareto substitution relationship or negative synergy between attitude and subjective norms. These results underscore the importance of taking into account potential nonlinear relationships between key constructs in IS acceptance research, and point to the need for more research. Theoretically, nonlinearities encourage new propositions regarding the conditional relationships between key constructs in TRA/TPB-based models in different contexts and can provide alternative explanations to understated or overstated main effects. Practically, nonlinear relationships may help clarify the level of effort or investment practitioners can exert in order to influence key antecedents of IS acceptance. Subscribing to the ontological stance that every theory is a contingency theory (Drazin and Van de Ven 1985), the present study views the omission of nonlinear relationships in model testing to be potentially misleading, and therefore as a possible limitation. As such, it is hoped that the present study will encourage researchers to more systematically take into account potential nonlinear relationships between key constructs in their research models.

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